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OF THE

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OF

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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

[2nd November, 1904.]

MR. ROBERT COCHRANE, I.S.O., President, in the Chair.

THE LORAIN SURFACE CONTACT SYSTEM OF ELECTRIC TRACTION.

By JOHN ROCHFORD, Assoc. M.

THE Borough of Wolverhampton is to be greatly admired for the bold stand taken in the face of persistent opposition by adopting a system of tramcars free from the numerous deadly dangers of the overhead or exposed live wire system, and shows that her representatives have done better than even the City of the Empire.

The introduction of electric light in the cities and towns of America was hailed with delight by the people, but after a time the overhead method of carrying the live electric wire to the lamps was found to be exceedingly dangerous, and the various corporations and communities decided that it could no longer be tolerated, and suggested that the live electric wires should be placed underground, to be out of the way of doing bodily harm to the people, because when overground or exposed a great danger existed should telegraph or telephone wires break and fall across the live wire, in which case the operators of the instruments, either telegraph or telephone,

would possibly be seriously injured if not killed; besides the danger also of the live wire itself breaking and falling down, and so making contact with the earth.

It is needless to say great objections were taken by the Electric Syndicates to this order, but the authorities, seeing that the lives of the people whom they represented were in danger from the exposed overhead system of high voltage electric live wires, would not relax their orders, and the Syndicates had to wake up to the situation of either taking away their electric light lamps in a given time or conform to the law laid down by the district. Thus it was that the ingenuity of inventive thought of the American engineer soon overcame the difficulties which at one period seemed insurmountable.

The same trouble took place with regard to the overhead system of tramcars; the same dangers, but to a greater degree, being attached to its overhead wire. To mention the various accidents that have taken place would be a big task, and suffice it is to say that within the present year several very serious casualties have occurred. In one case two horses, traced together with iron chains, were roasted to death by a live wire falling, and it was by the merest chance that the driver escaped.

For this necessary reason the system of overhead wires are prohibited entirely in New York and Washington, and other cities have clauses in their franchises which obliges the railway to discard overhead trollies when a suitable underground system was available at reasonable cost.

In consequence of the above, various surface contact systems have been designed, with extremely ingenious contrivances for carrying the electric current with as little leakage as possible to the various motors, each system having something in advance of the others.

The Lorain System has the advantage of running directly

off its own special system on to the overhead or trolley system if required. The Lorain is more expensive to lay down, and its up-keep is greater (that is, so far as has been ascertained in Wolverhampton, the first town in England to adopt the system). However, the prospect of less cost, both as regards construction and running, has been wonderfully modified within a period of less than two years. In one case alone, where a portion of the car had to be renewed after running 300 miles, it has now run over 18,000 miles, and is still in good working order.

It is difficult to get at the exact figures for the various expenses of running, as the Corporation which owns the system also owns the electric lighting of the Borough, and the combined generating power is in the one station.

In the Accounts, as published by the Wolverhampton Corporation, for the year ending 31st March, 1903, the financial results of year's working ending March, 1903, shows a profit of £2,479 4s. 2d., after setting aside a sum of £7,615 9s. 6d. for interest and sinking fund.

The Charges made for Electricity.—Lighting, 5d. per unit on a maximum demand used for an average of 1½ hours per day, and 2½d. per unit for all consumed in excess of this. A special rate of 4½d. per unit is charged for private houses, churches, and chapels.

For power and heat, 2d. per unit on a maximum demand for an average of two hours per day, and 1d. per unit for all consumed in excess of this. The terms "maximum demand" means "the largest number of lights or amount of power used at any one time during each quarter."

The erection and equipment of these works was completed in January, 1895, being formally opened by Lord Kelvin, and since this date the supply of electricity has been continuously maintained. The present capital expenditure is £136,086, with a capacity of 54,578 lamps of eight candle power.

The buildings at present consist of a main generating station and three sub-stations. The system of supply is continuous current distributed on the 3-wire system at a pressure of 440 volts between the outer mains, and a standard pressure of 220 volts for the supply to consumers' premises. The outlying portions of the town are supplied by motor transformers, the driving current of which is applied at a pressure of 2,000 volts from the generating station, and is transformed down to the standard pressure of 220 volts.

The plant at the generating station consists at present of six complete generating sets, as follows:—One 200 B.H.P. Belliss two-crank, high-speed, compound condensing engine, direct coupled to a Parker two-pole dynamo, 140 kilowatt 2,000 volts. This generating set is used for street lighting and for supplying current to the motor transformers in the outlying parts of the borough. Two 350 B.H.P. Belliss, three-crank, compound condensing engines, direct coupled to Parker's dynamos, each 220 kilowatt 550 volts. Two 880 I.H.P. Willan's three-crank, compound condensing engines, direct coupled to 500 kilowatt E.C.C. multipolar generators 550 volts. One Davey Paxman 800 I.H.P., three-crank, compound condensing engine, direct coupled to 500 kilowatt E.C.C. multipolar generator 550 volts.

All these generating sets are also available either for electric lighting or tramway traction.

The three Belliss engines are arranged to exhaust into a surface condenser supplied by Messrs. Joseph Evans & Sons, of Wolverhampton. The Willans engines and the Davey Paxman engine each exhaust into a separate Ledward ejector condenser, which is supplied with circulating water by a Gwynne centrifugal pump, direct driven by a 20 H.P. Parker motor.

The combined lighting and traction switchboard was

supplied by Thomas Parker, Ltd., to the design of the chief engineer.

The boiler-house contains six Lancashire boilers, 30 feet by 8 feet, and two "Economic" boilers, 14 feet 6 inches by 9 feet 9 inches, two economisers, and the necessary feed pumps, &c. These boilers work at a pressure of 130 lbs. per sq. inch.

The chimney is 115 feet in height, and is of circular section throughout inside, and an induced draught exhaust fan has been installed to improve the draught of the chimney.

A water-softening plant is in use, and has a maximum duty of 2,000 gallons per hour.

A large battery room has been built over the present boiler-house for the purpose of containing two storage batteries; one of 260 Tudor cells for lighting purposes, and one of 263 cells for tramway work.

The success of the Lorain system may be judged by the Corporation having had two years' experience of its working, and they have now contracted for extending it in various directions to meet other systems of electric current supply.

The published estimates for extension shows the estimated cost of this system against the overhead system; stating the former to be estimated at a somewhat greater figure. How this will work out remains yet to be seen.

Total Estimated Cost for all the New Routes—

	Capital Expenditure Double Track	Annual Expenditure Double Track
Lorain System ..	£69,989	£6,779
Overhead System ..	62,089	6,050
Difference	£7,900	£729
	Single Track	Single Track
Lorain System ..	£63,256	£6,466
Overhead System ..	57,445	5,833
Difference	£5,280	£633

The large proportion of the small increased working expenses with the Lorain System was for the electric current, and that would go to the Electricity Committee of the Corporation.

The total lengths to be constructed are :—8 miles 3 fur. 5 chs. length in single track for overhead system, or 7 miles 3 fur. length in single track for Lorain System.

316,647 estimated car mileage per annum over the above mileage.

The present low cost of maintenance can be readily appreciated by the fact that it now requires but one thirty-two-shillings-a-week man on duty to do all the necessary work of maintaining the present 11½ miles of track equipped, and less than an average of three hours a day of this man's time is required, there being no necessity for keeping tower wagon, horses, driver and lineman for emergency work. The one man alone, with an ordinary handcart, is able to make all necessary repairs.

The Lorain Surface Contact System, as has been frequently pointed out, combines the advantage of the Conduit System in doing away with overhead wires with a cheapness of construction which almost vies with the trolley-wire method. The cost of operation per car mile, the Wolverhampton experience has shown, is just about the same as in the case of the trolley wire method. Some trolley lines in the country are run at a lower figure than that obtained in Wolverhampton, while others are run at a higher figure, so that it is safe to assert that the working expenses per car mile, including maintenance and repairs, will probably not be above the average of trolley lines, and may be slightly below it. As to the reliability of the special mechanism, that has been sufficiently proved at Wolverhampton. Besides that the trouble of breaking the trolley wires is eliminated, which breakage in the United Kingdom has been responsible for the sacrificing of several human lives and many horses, neither is there a

slotted conduit to require constant cleaning out or to get filled with water and mud during rain-storms and street sweeping, and so cause a stopping of the tramway. The latter point is very material in Wolverhampton, where the streets, as in most manufacturing towns, are much dirtier than in places like London and Bournemouth. Yet, even in London and Bournemouth, it is whispered that the cost of cleaning the conduit and the slot-points, and keeping the latter in repair, threatens to be considerably higher than was originally anticipated. It is easy to speak with confidence of the Lorain System now, but two years ago it was a very different matter when there was *à priori* prejudice against all surface contact systems. The Lorain Steel Company are to be congratulated on their success in inducing a municipality to make an experiment, on a sufficiently large scale, in order to show in this country the merits of the system. The importance of the experiment is all the greater when it is remembered that there is not a yard of the Lorain System in operation in the world to-day outside of Wolverhampton. The initial trials took place on a short experimental line in Washington. The Wolverhampton Corporation, however, did not spend months in vain in their preliminary minute investigation of the Lorain System, and their opinion then formed has been justified by the results.

The Lorain System is identical with the trolley system so far as the arrangements for the current are concerned up to the section pillars. From these the wires, instead of being taken overhead, are insulated and placed under the tracks, as shown in the diagram (Figs. 1 and 2). At Wolverhampton, to meet the preference of the Corporation, these underground wires are laid on Callender's solid system, but the Lorain Company are prepared to use a drawn-in system, as the wires can then be removed from the pipes without difficulty if required, without disturbing the paving. The appearance of

the track after the cables have been laid, but not connected to the boxes, and the concrete has been laid down, is shown in Fig. 3. The insulated wire, which is of .05 sq. inches in section, is brought up about 6 inches above the concrete at the point where a contact box is to be inserted, looped and taken underground again to the next box, and so on until a section pillar is reached. The next step is the placing of the contact boxes in the spaces left for them between the rails, shown in Fig. 7, and the connecting of the underground wires to them. Then comes the paving of the track in the usual way, and the line is complete (Figs. 4, 5, and 6).

It will be seen that the actual installation of the system is effected rapidly, and, if necessary, it can be done without very great disturbance of an existing track. The contact boxes are manufactured and delivered complete, ready for insertion in the road bed. At Wolverhampton the boxes are placed at intervals of 10 feet apart, as single truck cars are used. If bogie cars were used exclusively the interval between the boxes could be increased considerably, thus decreasing the number of boxes required per mile of track.

The essential feature of the Lorain System, and the one which differentiates it from all other contact systems, is the contact box and the magnets carried on the car for operating same. Its various parts are illustrated in Fig. 7, and sections are given in Figs. 8, 9 and 10. Fig. 8 shows also the position of the magnet and the collector shoe on the car. As will be seen, the box consists of two main parts—a base of insulating material, known as reconstructed granite, and a metallic cover fitting into a recess in the top of the base. This cover measures 15 inches long by $9\frac{3}{4}$ inches wide, and is held in place by two nuts, on the removal of which the cover and cup of insulating material containing the contact apparatus may be lifted out for inspection or replacing, an operation requiring only about two minutes. The cover of the contact box consists of three

sections, two of which are of iron, and one, the central piece, of special steel, which is of non-magnetic composition, and extremely hard. Covering the top portion is a small removable wearing piece of the same material secured to the non-magnetic centre without the use of screws or bolts. This removable centre will last from four to six years with a five minutes' car schedule before requiring to be replaced, and it is then easily renewed at a very small cost. The centre of the cover—the highest part of the box—is never more than $\frac{3}{4}$ inch above the paving.

Immediately under the cover is a space in the granite base for the reception of the insulating cup, in which the contact is made when the car magnet is over the cover. Below is an opening in the base, in which is fixed a cylindrical casting, the bottom of which enters the Y casting for protecting the cables arising from the troughing, and the top part supports the cable terminal insulator. The cable ends are mechanically clamped, and also soldered to the terminal, thus making a perfect electrical connection.

All the details of these arrangements are clearly indicated in the several views, which also show the interior of the contact cup. This cup is made in two sections, capable of being hermetically sealed by means of a gasket and annular screw ring. In the top and bottom of the cup are two brass terminals moulded into the insulating material. The top terminal is screwed into the under side of the metal cover of the contact box, and supports the cup. The bottom terminal connects the contact pieces, or circuit closer, inside the cup to the cable terminal by means of spring contacts, which clamp a tongue on the cable terminal.

Through the cable terminal and the terminal situated at the bottom of the contact cup the current passes into the hermetically sealed cup to the lower part of the circuit-closer. This consists of a soft iron plate, $4\frac{3}{4}$ inches long, 2 inches wide,

and about $\frac{1}{16}$ inch thick, to which is secured a carbon contact plate about 2 inches in diameter, forming the armature, which is acted on by the magnet on the car as it travels over the box. The armature rests normally upon a circular ledge in the interior of the cup, and is connected to the lower brass terminal of the cup by means of a thin strip of hard rolled copper, about $1\frac{1}{2}$ inches wide, folded upon itself as shown in Fig. 9, representing a longitudinal section of the cup, and Fig. 7, in which the various parts of the contact box complete are presented by photographic reproduction. This connecting strip makes the electric connection to the armature without introducing guides or friction, and at the same time directs the armature in its vertical movement. On rising, the carbon top of the armature comes into contact with another carbon contact, rigidly secured to the top of the cup, and permanently connected to the contact plate in the roadway. Taking the arrangement as a whole, it is difficult to conjucture a simpler device, or one that could be more positive in action. The armature must fall to the disconnected and normal position by force of gravity as soon as the attracting force of the magnet on the car has passed. In some other systems where the electromagnetic mechanism is placed below the surface, some difficulty and positive danger has arisen owing to the fact that after the passage of the cars the contact studs have been left alive in the streets. In the Lorain System the switch, the only moving part, is a purely mechanical device without any magnet coils, defects in which would, in some other systems, cause more or less difficulty. The simplicity of construction has made it possible to place the switch in the hermetically sealed cup into which no moisture can penetrate, thus ensuring a long life for the apparatus. To effectually exclude any moisture leaks from the cable terminal, insulating oil, specially designed for the purpose, is run into the vacant space, around the lower part of the insulating cup. As the oil is heavier

than water, any moisture that may enter will rise to the top, where it can do no harm. The oil has been found not to thicken in lowest winter temperature, and not to deteriorate in any way.

Exhaustive tests of the boxes have been made by Mr. Shawfield, Borough Electrical Engineer of Wolverhampton, at the electricity works, with a machine specially devised to effect an enormous number of contacts. The box during the experiments has been subjected to abnormal tests, and has given remarkable results.

In the car equipment the peculiar feature of the Lorain System consists of attaching to the truck the magnets and current collector. The car wiring includes provision for taking current from an overhead trolley wire, in case the car should be worked on a combined system. This feature promises to be taken advantage of at Wolverhampton, if the great talk about intercommunication means anything. The ease with which a car can be run from a trolley section to a contact section is one of the advantages claimed for the Lorain System. The point is one of much importance, for the utility of most city tramways would be greatly interfered with if through services from outlying trolley sections could not be provided. The objection raised to the equipment of trolley cars with contact apparatus on the ground of the weight of the apparatus has little force, as the mechanism on the car required for working over the Lorain System weighs less than a ton.

In Figs. 11 and 12 views are given of the magnets, shoe and truck. The magnet, which is for operating the circuit closer in the contact boxes, is composed of a number of yoke cores, the ends of which are connected by iron plates, forming two parallel magnet poles. The poles are formed of a number of separate plates rigidly connected together by wooden pieces firmly bolted to the plates, as indicated in Fig. 11. The

magnetic path through the cover of the contact box and the armature within may be traced in Fig. 8. In the excitation of the magnets, the magnetic lines pass from the keeper through the core *C*, the pole piece *F*, and space *S*, iron cover *L*, and intervening space to the armature *AA*, which, as previously stated, rises, thus bringing together the contacts *D E*, and delivering current through *O* to the collecting shoe *H*. The magnetic lines continue on the other side back to the keeper *KK*. As the magnetic path through the cover and armature is short, the travelling magnet requires to exert only a small amount of energy to actuate the circuit closer.

The energising coils have a compound winding, one being in series with the motors, and the other being a shunt-winding for the normal tramway voltage. The series winding serves to strengthen the magnet in case an unusually heavy current to the motors has caused an abnormal drop in voltage, thus weakening the excitation due to the shunt winding, and to cause the pressure on the contacts to increase as the current passing through them to the car motors increases.

Eight small accumulator cells are connected to the terminals of the series winding, which are used ordinarily only for the purpose of starting the car from the depot or in case the line current has failed temporarily. The motorman will then energise the magnets from the battery circuit. It is unnecessary to remove the batteries for charging, and it is only necessary to charge them every two to three weeks, and less than forty ampere hours is required for each charge.

Current is taken from the contact boxes by a continuous collecting shoe, shown in the drawings, about 12 feet in length, which bridges the distance between two boxes, thus providing for a continuous collection of current. The collecting shoe is made shorter than the magnet under the car, so that the circuit within any box will be closed before the current collector impinges upon it, and also that the contact may be maintained

until after the shoe has passed over and off from any contact. This arrangement prevents any possible arcing within the boxes, because, at the time the circuit in any box is opened or closed, no current is passing, the collecting shoe already having passed to the next box. The current collector or shoe is placed between the magnet poles, and is composed of three continuous members firmly secured together, a contact strip of non-magnetic material, a piece of rubber and linen hose, and a wooden support. The latter is secured to the magnet yokes by bolts, allowing for all necessary adjustments. The shoe appears to have a suitable degree of flexibility, and it makes very little noise. In fact, except in very dry weather, when the track is covered with dust, the passage of the contact bar over the studs cannot be detected by the ear.

Fig. 13 is a view of the Corporation's car depot, which is equipped on the Lorain System. The inconspicuous appearance of the tops of the contact boxes in the paving may readily be noticed.

Experience has shown that earthing devices cannot be made to work practically, and the Company now decline to use or equip with them, and they are not required with the Lorain System.

Car Bodies.—The bodies of the cars now in service were made by Messrs. G. F. Milnes & Co. The top-seat car is arranged to carry 22 passengers inside and 26 on the roof, and is of the standard type, fitted with reverse stairway, giving easy access to the roof. The exterior is tastefully painted in green and yellow, with the Corporation Arms emblazoned on either side. The interior of the car is handsomely finished in oak framing, with ash panels, a bevel-edged mirror being fitted in the end framing of the car at each end. The ceiling is of three-ply birds' eye maple veneer, varnished and decorated, and relieved by oak mouldings. Three-ply perforated birch veneer, suitably curved for comfort,

is used for the seats, over which are spread loose rugs, of neat design, with the Corporation initials woven in the centre. Oak hand-poles, fitted with leather hand-straps, are suspended from the roof by ornamental polished brass brackets on either side of the car. There are three windows on each side of the car, and two at each end, of best British polished plate-glass. The side windows are provided with curtains of old-gold damask, which slide upon brass rods, and are looped at the sides by brass curtain holders. The interior of the car is lighted by six 16-candle-power incandescent electric lamps, in fittings of chaste design. Ventilation is afforded by six ventilators on each side, arranged to give the maximum of ventilation without draught. These are glazed, and are intended to be utilised for displaying advertising transparencies.

The stairs are easy of access, and fitted with brass hand-rails, treads being fitted with non-slipping iron. The seats of the roof are of the garden type, and all reversible. The roof is surmounted by a stout railing and a wire screen to afford protection. Collision fenders of angle steel are fitted to the ends of the car, and a powerful search-light is recessed into each dash. Life-guards of the "ordinary" type are placed at each end. A destination or route indicator is placed at each end in a prominent position, the route inscription on which is easily descernible by day, and it is fitted inside with lamps which at night render it distinctly visible for some distance.

The single deck car is intended to carry passengers inside only, not being fitted with seats on roof. It is arranged to give seating accommodation for 26 passengers. This car is fitted and finished inside on similar lines to the top-seat car.

The combination car is designed with a closed compartment in the centre, and with transverse seats at each end in open compartment. The closed compartment will accommodate 16 passengers. It is fitted with two windows at each side,

and fitted up in the same style as the interior of the top seat car. There are two open compartments, one at each end of the car, each compartment being fitted with two seats and accommodating four passengers each. Blinds are provided on each side of the open compartments, sliding in groves in side pillars, fitted with spring rollers and attachments, and arranged to slide down to the level of the seats. The roofs of the open compartments, as well as that of the closed compartment, are provided with ceilings of three-ply bird's-eye maple veneer, tastefully decorated, and both of the closed and open compartments are fitted with incandescent electric lamps. All cars are constructed according to the latest practice, thoroughly substantial in design, though neat in appearance, and are tastefully fitted up.

The two units used mostly for traction purposes consists of Willans and Robinson engines, and Electric Construction Company's generators, each of 500 kilowatt capacity. Traction panels have been added to the switch-board.

A fine car shed has been erected in Bilston-road, capable of housing 60 cars. It is well supplied with pits, and at the rear a repair shop is fitted up beneath the floor of the shed, an arrangement that will be a great convenience in making repairs, as cars can be run over the shop and the motors lowered directly to the floor.

The arrangements throughout show that the Tramways Committee and the municipal officials have approached the question of providing the public with Tramway facilities in no perfunctory spirit. They have considered the local conditions very carefully, and have not hesitated to enter upon experiments which, although they may be considered by some of very problematical advantage, may, on the other hand, prove a source of much benefit, not only to Wolverhampton, but also to other cities.

THE PRESIDENT said they were all greatly indebted to the author for bringing before them this interesting description of the Lorain System of Surface Contact. He understood that it was only in use in one town for the past two years, and that the mileage worked was about 11 miles. It was hardly sufficiently well known as yet to be introduced elsewhere. In a short time there would be extensive undertakings in different parts of the country, as, for instance, in Belfast, where it was proposed to spend about £85,000 in extending their tramway system and for the purpose of working the horse tramways by electricity. In Birmingham it was proposed to spend upwards of £1,000,000 in extending the city tramways and electrifying the system. In these two places there would be an opportunity of introducing new systems.

The great advantage that this system seemed to have was the avoidance of danger. This was a thing that was not to be minimised, though the accidents from the overhead system were not so frequent now as they were some little time ago.

There were some details in connection with this system that required some very careful consideration with which only experts could deal properly. He was sure there were some of their members present who would be able to express an opinion appreciative or otherwise as to the merits of the system which had been so ably placed before them.

They had heard something of this system before. He could not recollect at the moment where it was, but he thought it had been described elsewhere. Probably some of the members were not altogether unacquainted with the system about which the author had told them, and if so they would be glad to hear some remarks from them.

At the conclusion of the discussion—

THE PRESIDENT said he thought the author had every right to be well pleased with the very interesting discussion that his paper had brought forth. Though some of the remarks had not tended altogether in an appreciative direction, still, on the whole, the author should feel gratified, and they were greatly indebted to him for bringing the subject before them.

MR. M. RUDDLE said he was not an expert in tramway work, but he had some general knowledge of the running of the various systems of electric tramways. He must say he was rather disappointed with the paper. He thought it did not give them very much information from an engineering point of view. He could not altogether agree with the author in the conclusions he had come to. He did not know whether Wolverhampton was to be congratulated on being the pioneer of this system. It was an entirely new system. It had never been tried in practice—beyond an experimental run in the Lorain Company's own factory—before it was tried in Wolverhampton. He remembered the time it was introduced there, for he was very much interested in the controversy that took place. He noticed that the author claimed that this system was freer from danger to people and animals than the overhead system, and in one part of the paper it was stated that no accidents had taken place. With regard to that, Mr. Shawfield, Borough Electrical Engineer of Wolverhampton, who has charge of the works, read a paper before the Association of Electrical Engineers, and he took a different view, for in the opening part of his paper he says:—"In only one case has the shock received from a live stud been attended with serious results, and this occurred on February 17th, 1904, when a sheep and a dog were electrocuted through treading on a faulty box

on the Tettenhall Road Route." He also stated that a number of animals had been thrown down by coming in contact with live studs, though no serious results occurred. It was not very pleasant to contemplate that in large cities like Dublin and Belfast there was a liability for horses to be thrown down, and from this cause he was afraid it would not be quite safe. Another thing to be remembered was that at Wolverhampton there was only a very small length of track, and it had only been in use a very short time. Compared with the great mileage that was run over the world with the overhead system, he thought the proportion of accidents, in the proportion of the relative size of systems, would be found very much higher in the surface contact system. Another part of the paper states that the working expenses were practically the same as the overhead system. Mr. Shawfield, in his paper already referred to, does not quite agree with that. He states—"It must be admitted at the outset that from the point of cheapness of operation and maintenance no system of electric traction can rival the overhead system." A little further on Mr. Shawfield also states that "the total additional current consumption to be debited against the surface contact system is in this case 42 units per car mile, or approximately 19 per cent. in excess of what would have been required by the overhead system."

He saw the weight of the equipment required in the case of the surface contact system was one ton, and that in excess of the weight of the car. That was a very considerable proportion, and would have a very serious effect on the cost of maintenance. He thought the amount mentioned by the author for maintenance was rather small. Mr. Shawfield had doubled it.

He considered it was rather too soon to pronounce any

decided opinion in favour of this system. There had been a great many failures in surface contact systems, and this system required a trial on a very much more extended scale. Like all other new things it must stand the only proper tests which these things can be put to, and that is the test of time, before very much can be said of it.

Mr. P. H. Stewart said he was very much interested in the paper, but Mr. Ruddle had raised some of the points which he had intended calling attention to. He thought the cost of maintenance must work out more than what had been stated by the author. He understood it was necessary to test all the boxes near crossings every day, and the whole of the boxes once a week, and could not see how one man could do all the work. He thought it was hardly fair to compare the overhead system to the Lorain System with regard to accidents, considering the few miles there were of the Lorain System and the large number of miles of the other. Probably there would be more accidents only for the great care exercised. With reference to the horses being thrown down, there was not much satisfaction in knowing that whilst you were safe from an electric shock you ran the risk of a broken neck or something of the sort. The line had only been laid down for two or three years, and the surface of the track is not flexible. Probably in two years' time the track will wear uneven, and there will be trouble with the surface contacts. He would like to know if there were any precautions against this. These were things which could only be found out by time.

Mr. Tomlinson said there were two objections to the Lorain System, and he thought either of them would be fatal. One was the extra weight of one ton on, say, five tons, and the other was the number of contacts that

could go wrong. In every mile there were 528 contacts to be made and broken. He thought the dangers of the overhead system must be enhanced in this system, in which you have 528 possible live points. The dangers of the overhead system appeared to be exaggerated. He considered the Lorain System had not been tried for a sufficiently long time or on a sufficiently big system to give data for final judgment as to its practical success as compared to the overhead system.

Mr. Lilly said he had the pleasure of being in Wolverhampton at the time of the Exhibition, and he then saw the Lorain system in operation, but he had not time to visit the generating station. He took the trouble of having a look at the working of the system, and at that time he must say the whole system seemed to work satisfactorily. One thing he noticed particularly, and that was the great care used in the working of the installation, particularly at the contact points. These seemed to be tested daily. That struck him as being a rather objectionable feature of the whole system.

Compared with the overhead system, of course the Lorain system had many advantages. No one would say that the overhead system is by any means an ideal one, but experience has proved that it was both cheaper in the first cost and cheaper to run than any underground system yet devised. In cities sometimes it was found necessary to revert to the underground system, as had been done in London, but it was only because they would not be allowed to have the overhead system. All underground systems were of necessity much more expensive than the overhead. All the circuits had to be insulated properly. The great thing they had to consider was the testing of the installation and the first cost.

In the Lorain System they had no continuous contact.

They had the intermittent contacts, and as already mentioned this was a serious defect. They had to consider the immense number of times these contacts were made, and whether they would work as well after the system had been working for some time and the surface got worn in places.

The conduit conductor had been unduly criticised. Of course it had its defects, such as the flooding of the sections, &c. This had caused serious trouble with short circuits, but these difficulties had been got over, and he saw no reason why the ordinary installation of the conduit conductor would not be as good or even better than the Lorain System.

These comparisons, however, were hardly to the point, for they were only dealing with the Lorain System itself. But they must remember that the Lorain System is only one of many systems working with surface contacts, although it was the only one he knew of really practical value.

Mr. A. D. Price said the Institution was to be congratulated on having brought before them a paper on a subject of such general interest. He was in the position of an interested learner, having, twenty-three years ago, been associated in the construction of the tramway to the Giants' Causeway, which was the first electric tramway constructed in the United Kingdom. There the system adopted was the insulated live rail, which had since been superseded by the overhead wire and trolley system. He thought the paper was deficient in one respect—in that it did not give a clear comparison of the cost per mile of double track constructed on the Lorain System as against a mile on the Trolley System. This, he considered, would be a valuable addition to the paper.

So far as he had been able to ascertain the general

view was that the Trolley System is considerably cheaper, both as regards the capital cost of installation and the annual cost of operation and maintenance. The figures given were:—

One mile double track equipped on Lorain System - - - - -	£16,600
One mile double track equipped on Trolley System - - - - -	14,000
Difference per mile - -	£2,600

Mr. G. M. Harriss said if the paper had a fault he thought it was in the direction of making an attack on the overhead system, which was unnecessary for the author's purpose, which he assumed was to explain the Lorain System.

It is true there were recent unfortunate accidents for which overhead wires were responsible, but the reason was that the wires came down, and with an overhead system of traction it was absolutely essential that the wires should not fall. There was no reason why they should fall if properly erected any more than a bridge or other structure should fall.

He did not wish to minimise the danger, because the conditions of electric traction, as we know them, demand that the car shall be in constant metallic contact with a cable, so that the energy may be picked off it as the car goes along, and for commercial reasons we know that the electrical pressure at which the energy is transmitted is sufficiently high to be dangerous to life, and while these conditions prevail, and the cars are run through busy thoroughfares, there must always be a certain amount of danger.

Comparing the overhead system with the Lorain he thought that the Lorain, or, indeed, any other under-

ground system, had real dangers, and while the overhead system was also attended with danger that danger was very apparent, and the fact of it being so apparent he thought made it less real.

Whatever Mr. Ruddle might think as to the wisdom of the Wolverhampton Corporation in introducing the Lorain System he was sure Mr. Ruddle and every engineer would agree they owed the Corporation some gratitude for making the experiment. Of course, some might think it was hardly the direction for ratepayers' money to go in, but the end justified the means, and all is well that ends well.

MR. ROCHFORD, in reply, said he had not the pleasure of having Mr. Shawfield's figures when this paper was written by him, as it had been intended to be read before the Institution during last Session, but it was kept over. The expense of 32s. per week was correct at the time the paper was written. Since then a second man had to be employed—that is, two men to do the work—as the mileage had been increased. With regard to the accident that was mentioned, he thought the speaker might have said all that Mr. Shawfield said about it, because it was rather interesting. It happened in winter time, when there was snow on the ground, and at the place where the accident occurred there was a dip in the road. The place was partially flooded, and salt had been thrown down to prevent the snow from freezing. The box was cracked by an unusually heavy load of about five or six tons having been concentrated on it, and the salt water got in and made contact. There was a flock of sheep coming along, and one of these stood on the box. It got a shock and fell down some distance from the box. The sheep dog ran over and got hold of the sheep to pull it up. The dog then got a shock from the sheep and fell

down. He did not know how it was managed, but that was the explanation he got when he inspected the locality.

He thought Mr. Shawfield's paper was published about eight months after he had written this paper. His object was to bring information before the members, not to discuss the difference between the different systems. If some gentleman would bring in a paper on the overhead system then they could discuss that. In going into the matter of the Lorain System they might find something that was not quite perfect, but he was also sure that the overhead system was not perfect. They had an incident that occurred at the corner of Nassau Street and Grafton Street, Dublin. A gentleman was passing one of the pillars and he fell down. Someone said he had got an electric shock, but the gentlemen connected with the overhead system said that was impossible. Then they had the case in Dudley, where the horses were coming along, and the pillar of the overhead system was in the centre of the road. This pillar got alive with electricity, the first horse was seen to swerve towards the pillar, and fell down. The current went through the horse and through the chains on to the next horse, and they were both roasted alive. They thus saw these pillars in the streets could be made alive if the insulators on the top of the pillar became defective. They might talk about the defects of the contact studs, but as the studs could be seen timid persons could avoid standing on them. But these things had only to be found out, and then some energetic gentleman found a method of removing the fault. It has been stated that a gentleman was seen standing on a stud that was known to be alive at 500 volts, and he apparently did not notice anything unusual. How many hundreds of thousands of insulators were there on the overhead system, even in Dublin, and if

one of these got broken the result would not be comfortable for anyone passing round about the posts. With regard to the channels in the road with an opening of $1\frac{1}{4}$ inch for the conduit system it had some defects. In London there was a little boy going along, dragging a chain after him. The end of the chain got into the opening, and the chain fell to the ground, and so did the boy!

[*7th December*, 1904.]

Annual General Meeting.

Mr. Robert Cochrane, I.S.O., President, in the Chair.

The Officers of the Institution for the year 1905 were balloted for and duly elected (see List of Council, p. 206).

The following candidate was balloted for and duly elected:—

Alfred Allman, as an Associate Member.

Mr. Robert Cochrane, President, delivered his Address as follows:—

Gentlemen,—

The custom of commencing the work of a new Session by an opening Address is now becoming general in all the professional institutions, and it has been found to afford a convenient opportunity of bringing under review the work accomplished during the period immediately preceding. My remarks will be devoted for the most part to what has occurred as bearing on our work during the year now almost closed, and in the first place I must return my sincere thanks for the honour you have done me in electing me as your President, and my second duty is to recall for a moment the memory of the fellow-workers and colleagues who have passed away during that period.

Members Deceased, 1904.

During the present year our roll has lost by death the names of three of our colleagues—Mr. Charles P. Cotton (died 10th March, 1904), Mr. Alexander Tate, and Mr. James Whiteford. Charles P. Cotton was perhaps the most widely known member of the profession in Ireland.

He died at his residence, Ryecroft, Bray, at the age of 72. In conjunction with Mr. Alexander M'Donnell he acted as Honorary Treasurer of this Institution for the years 1871 and 1872 under the presidency of Dr. Bindon Stoney, and was elected to the position of President for the years 1873 and 1874. He contributed largely to our "Transactions," and amongst the valuable papers read at our meetings may be mentioned those on "Inishannon Bridge," on the "Cork and Bandon Railway," published in Vol. 8; "Wire Rope Transit for Minerals," "Tidal Sluices," and "Beacon Failure, Aldern Rock," published in Vol. 10; "Concrete," and on "The Castleisland Railway," which were published in Vol. 11; "Prismoidal Formula," in Vol. 12; "Loans for Sanitary Purposes," Vol. 16, and a paper on the "Tansa Waterworks, Bombay," in Vol. 22.

He occupied the responsible position of Chief Engineering Inspector to the Local Government Board from 1879 until 1899. He was an able, impartial and painstaking officer, and by the professional men with whom he came in frequent touch he was regarded with the highest esteem and respect. In 1897, when under the "65 Rule" he had reached the age limit, and should consequently retire, his services were considered so valuable that he was retained by the Local Government Board, with Treasury approval, for two years longer. During his busy life he found time to publish several works—viz., a "Manual of Railway Engineering in Ireland," in 1861, which reached its second edition in 1874. He compiled a "Loans Manual" in 1890, "The Public Health (Ireland) Act, 1892," and "The Irish Sanitary Acts, 1878-1896." He was admitted a member of this Institution in 1861, and on retiring from active work was made an Honorary Life Member in 1902. He became a member of the Institution of Civil Engineers (London) in 1864,

and was elected Honorary Life Member of that body in 1903. I am indebted to Dr. Bindon Stoney, Past-President, for the following additional particulars:—The late Mr. Cotton was born in Dublin on 19th January, 1832. He entered Trinity College in 1848, and took his B.A. Degree with a Diploma of the Engineering School. In 1855 he entered the office of the late William R. Lefanu as pupil, and acted as resident engineer under him in the construction of the Bagenalstown and Wexford Railway, the Mallow and Fermoy Railway, and the Roscrea and Nenagh Line. When Mr. Lefanu became a Commissioner of Public Works, and retired from private practice in 1863, Mr. Cotton, in conjunction with Mr. B. F. Fleming, took over, and, as Engineers-in-Chief, finished the railway from Wicklow to Wexford, the Roscrea and Nenagh Railway, and the Shillelagh Branch Railway. He was engineer to the "Ballast Board," Dublin, the authority in charge of the construction and repair of Irish Light-houses, 1863-7. He was appointed in May, 1898, on the Royal Commission on Sewage Disposal, and in February, 1900, he was appointed Chairman of the Viceregal Commission to inquire into and report on the health of the City of Dublin.

Mr. Alexander Tate died at his residence, Rantalard, Whitehouse, near Belfast, on the 29th July in the present year at the advanced age of 81 years. He was elected a member of this Institution in 1844, and was its Honorary Secretary from the year 1855 until 1861. In the year 1862 he acted as joint secretary with Dr. Bindon Stoney. During his period of office Sir Richard Griffith, George W. Hemans, and Michael Bernard Mullins successively occupied the presidential chair. His resignation of the office of honorary secretary in 1861 was due to his removal to Belfast, when he was elected to the important

offices of County Surveyor for Antrim and for the County of the Town of Carrickfergus. These appointments had become vacant by the resignation of Mr. Lanyon, who had been elected Mayor of Belfast, and was afterwards Member of Parliament for that city. Mr. Lanyon had also been honorary secretary of this Institution. He was its first secretary, and served in that capacity in 1835 and 1836, during the presidency of Sir John Fox Burgoyne. The removal of Mr. Lanyon and Mr. Tate from Dublin—though to their professional advantage pecuniarily—prevented their probable election to the presidential chair, as the distance was too far to admit of attendance in Dublin, and the facilities now possessed for travelling did not then exist.

Alexander Tate was born in Dublin, and received his early training as Engineer and Architect under the late Jacob Owen, M.Inst.C.E.I., in the Board of Works Office. He had as his fellow-pupil the late Sir Charles Lanyon and the late Mr. Henry Smyth, County Surveyor for Down. At an early age he was appointed County Surveyor for one of the divisions of County Dublin, which position he filled with marked ability until his removal to Belfast in 1861.

In 1884 he resigned the Surveyorship of County Antrim and the County Town of Carrickfergus, and was succeeded by Mr. John H. Brett, M.Inst.C.E.I. Since that time he did not engage in the active work of his profession. He had always been interested in scientific research, and was a Life Member of the British Association, and acted as secretary of one of the sections of the Dublin Meeting in 1857. He was also a Member of the Royal Dublin Society, of the Royal Society of Antiquaries of Ireland, of the British Astronomical Association, and many other societies.

He was for over sixty years a member, and at the time of his death was "Father" of the Institution. Early in the month in which his death took place I had a letter from him apologising for his absence, due to ill-health, from our recent meeting in Belfast, in which he said—quoting his own words—"to prevent my being supposed to be unmindful of my allegiance to an Institution with which I have so many pleasant associations. As a member now for more than sixty years, and as one who for many years acted as its honorary secretary, I could not but have been solicitous that its reception in the city which so long has been my home should be worthy of it." His death removes a connecting link between the founders of the Institution—to whom we owe so much, but whose labours we are apt to forget—and the men of the present day.

James Whiteford, who died on the 25th of August last, in the 70th year of his age, at his son's residence at Prospect House, Carrickfergus, near which town he was born, was elected an Associate in the year 1881. He was well known in Belfast and the North of Ireland in several capacities. The principal appointment held by him was as Engineer and Surveyor for the Downshire Estates. At a sitting of the Land Court at Lisburn on 10th October last, the Commissioner, Mr. Edge, K.C., and the professional men present referred to the loss the Court had sustained by his death. His last public appearance was when giving evidence before the Arbitration Court in Belfast, presided over by my predecessor, Mr. J. H. Ryan, Past-President, in connection with the Belfast Water Act of

the death of Mr. Frederick Villiers Clarendon we o record the loss of another former honorary secre- of the Institution. He died at his residence, 36

Mountjoy-square, Dublin, after a few days' illness, on the 17th October last, at the advanced age of 84 years.

He was a Graduate of Trinity College. In 1839 he acted as assistant engineer in the erection of Kenmare Suspension Bridge. In 1841 he was engaged as Architectural Assistant in the Office of Public Works, and was afterwards engaged in supervising the erection of Clonmel Lunatic Asylum and Smithfield Prison. In 1844 he acted as resident engineer in the construction of Galway Docks and the Tralee Ship Canal. In 1846 he entered the permanent service of the Board of Works as Assistant Surveyor, and was appointed Surveyor of Works and Buildings in 1854. He retired in August, 1887, on full pension. Mr. Clarendon was justly esteemed as an able and conscientious officer in the performance of his duties. After his retirement he devoted the remainder of his life to charitable work.

He acted as honorary secretary of the Institution from 1847 until 1853, during the presidency of Colonel Sir Harry D. Jones and Sir Richard Griffith. He contributed several papers, including a description of the "Galway Dock Gates," published in Vol. 2 (1848) of the "Transactions"; "Dock Gates, Rollers, and Pivots," and "A Carriage to Carry its own Rails," published in Vol. 3 (1849).

Addresses of Past-Presidents.

The selection of suitable subject matter for a Presidential Address is probably not the least difficult consideration arising in its preparation. There is such a wide field in connection with Engineering that it is only possible to proceed by a process of elimination, retaining such matters as appertain to the immediate interest of the Institution or come more directly within the cognisance

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of the writer. A favourite method of treatment has been to pass under review the progress made during the immediate past. It will, however, be generally found that the professional magazines have in a measure forestalled the preparation of such a retrospect, and only such topics as may be most intimately connected with the affairs of the Institution in that particular year are left for consideration.

Our records show that we have had addresses from twenty-one of our Past-Presidents in a total of twenty-nine. Of the twenty-nine there are ten still living and in active and honourable connection with the Institution over which they have so worthily presided. It was not until the year 1856 that a Presidential Address was first given, and though the practice has not been uniformly followed since that date, but few instances have occurred in which it has been omitted.

These addresses range over every branch of Engineering science and Engineering practice, and I may here remark that it will well repay the younger members of the profession the time spent in their careful perusal.

Past-President Hemans, after some general remarks on the status of Engineers, devoted his address to the subject of railways. In 1859 he was followed by Past-President Mullins, who gave a valuable historical sketch of Engineering in Ireland. In 1861 an inaugural address was given by Sir Richard Griffith on the occasion of the first meeting of the Institution in the new buildings of Trinity College, in which, after a suitable reference to the work of the University and the position of the Institution, he made a lengthened reference to the report of the Railway Commission and the recommendations made by it. There was no address given from 1861 until 1866. In the latter year Past-President Mallet gave a short his-

tory of the Institution and its connection with Trinity College, touched on the subject of the education of the Engineer, and referred generally to the engineering projects of the period.

Past-President Anderson's address followed in 1867. He was the first purely mechanical engineer who occupied the Presidential chair. He confined his observations more particularly to manufacturing and mechanical science. In 1870 Sir John Ball Greene, in his address, reviewed the work and papers of the previous session, referred to the work in connection with the Suez Canal, Blackfriar's Bridge, and other important works.

Dr. Bindon Stoney's Presidential Address, delivered in 1872, opened with a notice of what was necessary for the professional equipment of the young engineer, a review of technical education, engineering prospects in Ireland, sanitary and mechanical engineering, iron and coal, the Mont Cenis tunnel, and other subjects of much interest—all treated with marked ability.

Past-President Cotton, in 1874—to whose recent lamented decease I have already referred—took up in his address the history of Engineering in Ireland from the end of the period covered in Past-President Mullins' address on the same subject in 1859, and concluded with some remarks on the position of the Institution. In 1876 Past-President M'Donnell reviewed the progress of engineering works lately carried out, and followed with some interesting statistics relating to railway traffic and permanent way expenses.

A new Charter of Incorporation having been obtained for the Institution in 1877, a reference to it occupied the first attention of Past-President Manning in his address in 1878. A short retrospect of engineering work in Ireland down to the year 1835 followed, and he also dealt

with Portland cement in sea works, the construction of tramways, and sewerage of towns. In 1880 the chair was occupied by Past-President Bailey, who had been trained almost exclusively in the mechanical department of engineering. His address dealt chiefly with the application of mechanical science to works then in progress, including a reference to "the battle of the brakes." Mr. Park Neville's address in 1882 was taken up with an account of the Dublin Waterworks. The presidential address of Mr. W. H. Mills in 1883 comprised a comprehensive survey of the most important works recently finished or in course of construction. In 1885 Past-President Aspinall dealt with "a number of subjects connected with modern engineering work," chiefly pertaining to mechanical engineering.

Past-President Griffith in 1887 commenced his address by a reference to the early history of the Institution, the desirability of registration for engineers, the testing of materials, improved means of water communication, and concluded with a full description of the Tay Viaduct and Forth Bridge. Past-President Harty, who occupied the chair in 1889 and 1890, adopted as a subject for his address the housing of the working classes in Dublin and other improvements in the city, including baths and wash-houses, new streets, paving and cleansing, and the water supply.

The Institution met for the first time in the new hall, erected on its own premises in Dawson-street, on 16th December, 1891. Professor Pigot, in his presidential address the following month, congratulated the members on the accomplishment of the project, and referred to the debt of gratitude they owed to the University of Dublin for providing them with a place of the meeting for the long period of thirty years. He addressed the members on the

extension of railways and harbours and upon the present state and possible improvement of our inland navigation.

In 1893 the address of the president—John Chaloner Smith—dealt principally with a consideration of the possible reduction of railway rates. The late James Price—whose lamented death during his term of office as president deprived the Institution of the continuance of his valuable assistance in upholding and maintaining the dignity of the profession—was succeeded by Mr. James Dillon, who, in his address in 1896, took for his subject "the public work that Ireland needs for the proper development of her resources, including her agriculture, deep-sea, and inland fisheries, and her great live stock export trade and other matters." In the year 1900 Mr. Edward Glover took for the text of his presidential address the working of the Local Government (Ireland) Act, 1898, and the Agricultural and Technical Instruction Act, which came into operation on 1st April, 1900.

The presidential address of Mr. John H. Ryan, delivered at the December meeting in 1902, comprised a general review of engineering progress, and enumerated some of the most important achievements of the previous years.

The foregoing scant outline of the subjects will show what a very wide field of professional knowledge and experience is included in those addresses They embody much solid information on the past history and practice of engineering in this country, which every young engineer in Ireland ought to be well acquainted with.

Work of the Past Session—Changes in the By-Laws.

The Index of the "Transactions," arranged under the heads of subjects and authors, which was completed in 1903, will be found most useful to those who wish to take

advantage of the Library. A catalogue of the contents of this Library has also been prepared for the use of members.

It is very encouraging to be able to record a marked advance during the present year in all departments of the work of the Institution. During the past Session there was a full supply of good papers, many of them of a class much above the average. For the first time in our experience it was found necessary to hold over some communications rather than unduly prolong the Session into the summer months. The difficulty experienced in getting papers has for the present disappeared, and it is hoped members will continue to bring forward their contributions both in papers and in taking part in the discussions which follow at our meetings.

The accession of new members is highly satisfactory. The total number who joined the Institution during the past Session is 25 of all ranks as follows:—Members, 9; Associate Members, 14; Associate, 2. This is an increase of $9\frac{3}{4}$ per cent. on the roll of the previous Session.

The Committee appointed by the Council in January last to take into consideration what, if any, changes should be made in the bye-laws, and to report generally as to whether any steps could be taken to further the interests of the Institution, held 15 meetings, and they have prepared a report suggesting changes, some of which are merely verbal, but some of the rules have been altered where it was felt such changes would increase the usefulness of the Institution. These revisions were framed with the intention of making our rules and practice conform with those of the Institution of Civil Engineers (London), and this has been done except in some minor points of detail, where a slight divergence was found necessary to meet local conditions.

The most important recommendation is that for introducing examinations for Students and Associate Members on the lines followed for many years with such success by the London Institution. It has been hinted at in some quarters, but not distinctly asserted, that it is easier to gain admission to this Institution than to the London Institution. When, however, the new rules are adopted and acted on there will be no grounds for anyone to be under misapprehension on the subject. It was considered a defect that the rules did not provide for submitting a yearly report and statement of accounts to the annual meeting so as to give members a fuller opportunity of becoming acquainted with the work done during the previous Session and to afford a legitimate means of discussing and considering such matters. For the future it is proposed to submit the Annual Report of the Council to a general meeting of the Institution.

Changes have been suggested in the dates for electing Council and officers. At present the Council and officers are inducted in the middle of each Session, which is inconvenient, as it necessitates over-lapping. The report for any one Session should be prepared and, if possible, presented by the Council in office during that Session. The changes suggested are made to enable each outgoing Council to report on the work done during their period of office. The appointment of an honorary librarian is recommended for the management of the library and making arrangements for lending books.

The Visit to Belfast.

An event of some interest to the members, as marking a step taken by the Institution for the first time in its history, is the visit of some forty of its members to the city of Belfast in June of this year. Although under-

taken on short notice, the visit was most successful, and the works seen were regarded with the greatest interest by those who were able to take part in it. Many of the principal residents expressed regret that a longer intimation of the proposed visit had not been given. The cordiality of the reception was well calculated to induce the visitors to repeat the visit.

The shipbuilding yards of Messrs. Harland & Wolff were visited on 15th June, and the new electric generating station was inspected under the guidance of Mr. Carlyle, a member of the firm. On the same day, by the invitation of the Belfast Harbour Commissioners, the new graving dock, now in course of construction, was visited. The Assistant Engineer, Mr. W. Redfern Kelly, M. Inst. C.E., conducted the party over the work, and to that gentleman I am indebted for some particulars of this important undertaking. On Thursday, 16th June, the members of the party proceeded in the Harbour Commissioners' steamer "Musgrave" down the river quays, under the guidance of Mr. W. Redfern Kelly, who pointed out the various improvements made in the harbour accommodation, and showed the new Musgrave Channel and other works. The new City Hall, in course of erection, was afterwards visited, and in the afternoon, on the invitation of Messrs. Davidson & Co., a visit was paid to the Sirocco Engineering Works.

On Friday, 17th June, the members travelled over the Belfast and Northern Counties section of the Midland Railway system under the guidance of Mr. Berkley D. Wise, the Engineer-in-Chief of the line, *en route* to the Gobbin's Path and the Giants' Causeway. The stations on this line have in many cases been reconstructed from designs by Mr. Wise, and the great architectural

skill and taste displayed by him in their erection afforded much gratification.

The chief social functions in connection with the visit were the reception by the Lord Mayor on the 15th and the dinner of the Institution on the 16th June. The Lord Mayor of Belfast, Sir Otto Jaffè, J.P., and Lady Jaffè, gave a reception in the Public Library to the members of the Institution visiting Belfast. A great many guests were invited to meet them, including the members of the Corporation of Belfast, the Harbour Commissioners of Belfast, and representatives of other public boards, with a large number of local gentlemen connected with the engineering profession. The Art Gallery, which contains many interesting works, was open to the visitors, and, in addition to the other exhibits, models were on view of the new graving dock seen that morning, and of Whitehead Railway Station, planned by Mr. Wise for the Midland Railway Company. I have, at the request of the Council, prepared some notes of the works seen in Belfast, to which I shall refer later.

The dinner given by the members on the 16th at the Grand Central Hotel afforded much pleasure to all present. An account of the proceedings and speeches will be given in the "Transactions" for the Session 1903-4, about to be issued. The advantage accruing to the Institution in making such visits as this are so manifold that they ought to form a distinct part of the work of each Session, and one should be arranged for each summer to places where important works executed or in progress could be seen.

Other Engineering Excursions.

It is somewhat remarkable as a coincidence that the present year is also the first occasion on which the Insti-

tution of Civil Engineers (London) ventured to leave their head-quarters in Great George's-street. It shows the tendency of the time to take advantage of the facilities for travel which now exist. The Exhibition at St. Louis was their destination, and the two other most important engineering institutions—viz., the Mechanical Engineers and the Electrical Engineers—also visited America and the Exhibition.

The visit of the Mechanical Engineers was in response to an invitation received from the American Society of Mechanical Engineers to hold a joint meeting at Chicago. They afterwards visited the Exhibition at St. Louis, and had opportunity of seeing the principal engineering works in that country, where they saw nothing very much ahead of the best establishments at home. They were struck with the energy which the foremen and workmen displayed, and were told that the best managers and workmen came from England, for which trades unionism in this country was responsible. When a workman saw his progress barred at home he went over to America, where he was gladly received, and soon improved his position.

The Institution of Electrical Engineers also made an American tour this year, and their visit is said to have been most instructive and enjoyable. The Exhibition was visited, and they saw many of the chief cities in the States and in Canada.

The Junior Institution of Engineers also visited the United States and the St. Louis Exhibition, in addition to which they had a summer meeting in Germany. Like the Society of Engineers founded in 1854 the Junior Institution make frequent visits to works during the year.

The Belgian Engineers came to England in September last as the guests of the Iron and Steel Institute

Amongst other places of interest visited by them was the National Physical Laboratory at Bushy Park, in charge of Dr. R. T. Glazebrook, F.R.S., on which occasion I had the privilege of being present.

The visitors, under the guidance of the staff, were intensely interested in examining and listening to the explanations of the uses and modes of manipulation of the many beautiful instruments and appliances to be seen throughout the various departments of the laboratory. The great practical utility of the work carried on afforded an excellent illustration of the application of science to the solution of the every-day problems which confronted the engineer, chemist, and commercial men in their work.

This laboratory is only partly subsidised by the Government—the Institution of Civil Engineers, the Institution of Mechanical Engineers, and the Iron and Steel Institute each contributing largely to the expenses of the establishment.

I have referred to the visits made by the principal Engineering Institutions during the past year to show that in the new departure we have just made in the matter of travel we have moved into line with the other Engineering Institutions.

The First Organisation of Engineers.

Many engineers are still under the impression that the Institution of Civil Engineers founded in 1817 was the first organisation formed for the advancement of the profession, and that our Institution, founded in 1835, comes second in point of time. I was also of that opinion until when recently engaged in the British Museum in another line of inquiry I discovered a facsimile copy of the MS. Minutes of a "Society of Civil Engineers" founded in 1771. The book bears on its cover the inscription, "Anº. 1771, Society

of Civil Engineers." The facsimile copy was made in January, 1893. Feeling that anything pertaining to such an early professional society could not fail to be of general interest, I made some extracts affording information as to the origin and constitution of this Society, presumably the earliest Engineering Society in the Kingdom."

For the first twenty-one years of its existence there were only three presidents, as follows:—

President 1771-1780—Thomas Yeoman.

„ 1781-1782—Christopher Pinchbeck.

„ 1783-1792—Robert Mylne.

From 1792 to 1841 there was no president elected, the principal officer being the treasurer. In 1841 it was resolved—"That it is expedient that the Society do annually elect a president." From that time—when Sir John Rennie was elected—to the present there were sixty-three presidents. In 1847 we find the name of Robert Stephenson, who was again selected in 1856. The list contains the names of William C. Mylne, President, 1853, and Charles B. Vignoles, President, 1866, and it comprises the names of all the most eminent members of the profession in London.* Charles B. Vignoles, F.R.S., was President of the Institution of Civil Engineers of Ireland during the years 1863 and 1864.

It was resolved on 30th March, 1792, "That in all elections for the future there shall be a distinction made in the admission of members. Candidates shall be elected as Civil Engineers by profession, and those who are not so to be called Honorary Members."

* The List of Members for 1792 is given as follows:—John Smeaton F.R.S, President; William Jessop, Robert Whitworth, John Rennie, Robert Mylne, F.R.S., Vice-Pres.; James Watt, F.R.S.; James Golborne, Sir Thomas H. Page, F.R.S.; John Duncome, Capt. Joseph Huddart, F.R.S.; Henry Eastborne, William Chapman, James Cockshutt.

In April, 1798, when Rennie, Mylne, Jessop and Whitworth were present, the following was agreed to and recorded:—"It was conceived it would be a better plan that members should dine together at a late hour after attendance in Parliament, and pass the evening in that species of conversation which promotes the communication of knowledge more readily than it can be obtained from private study or books alone." These meetings were held at the "Crown and Anchor" in the Strand every alternate Friday during the Sessions of Parliament.

It is also recorded that "as a mark of the Society's regard a tribute is always paid after dinner to the memory of the late worthy brother John Smeaton." Smeaton died in 1792, and at a later period we find the names of Mylne, Jessop, Watt, Huddart, Golbourne and Rennie similarly honoured at the meetings.

About the year 1812 the Society published a volume descriptive of Smeaton's works as "constituting a more substantial monument to his fame and character." In the preface there is a reference to the origin and early history of the Society, which is described in the rather ornate phraseology as having arisen under the following circumstances:—"Before or about the year 1760 a new era in all the arts and sciences, learned and polite, commenced in the country. Everything which contributed to the comfort, the beauty, and the prosperity of a country moved forward in improvement so rapidly and so obviously as to mark that period with particular distinction." . . . "The general situation of things gave rise to a new profession and order of men called 'Civil Engineers.' In all the polished nations of Europe this was and is a profession of itself. Academies, or some parts of such institutions, were appropriated to the study of it, and all the preparatory science and accomplishments to form an able artist whose

profession comprehends the variety of objects in which he is employed, and of which the present work is a sample thereof."

One of the most interesting features in the list of officers is, that from 1771 to the past year there were only five treasurers, all of whom come from the two well-known families of engineers—Mylne and Rennie. The Mylnes were engaged in Dublin in connection with the water supply. John Rennie designed the works at Kingstown Harbour. His great grandson, Mr. John A. Rennie, undertook the duties of treasurer of the Society last year. He is the sixth treasurer since 1771, and the third Rennie who held the office.

The Society now holds its meetings once a month for the first six months in each year. It is, as at present constituted, entirely a social society, and the number is limited to fifty members and hon. members. I have to acknowledge my indebtedness to Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S., a past-president, and to Mr. John A. Rennie, treasurer, for an opportunity of consulting a copy of the minute book, from which I have extracted the following resolution, agreed to for the formation of the Society, dated 15th March, 1771. This minute reads as follows:—

"Agreed that the Civil Engineers of this Kingdom do form themselves into a Society, consisting of a president, a vice-president, treasurer, and secretary, and other members, who shall meet once a fortnight on Saturday evenings at 7 o'clock, from Christmas or so soon as any of the country members come to town to the end of the sitting of Parliament, at the 'King's Head' in Holborn. It is further agreed that each member shall pay a forfeit of one shilling for being absent unless he is out of town. It is

also agreed that rules and orders shall be constituted for the well governing of this Society.

"Witness our hands—Robert Mylne, John Grundy, John Thompson, Joseph Nickalls, Thos. Gorman, J. Smeaton, J. King."

The "Society of Engineers," founded in 1854, and first known as the "Putney Club," is not in any way connected with the Society founded in 1771. The "Putney Club" owed its inception to the students of Putney College, an institution then existing for the education of engineers. In 1857 it received the title of the "Society of Civil Engineers." In 1863 the members first began to pay visits to works possessing special interest to engineers. During the present year it celebrated its jubilee, and has on its roll nearly 600 members. The present secretary, Mr. Percy F. Nursey, who has filled the office of president, has been associated with it since 1858.

This brief reference to the older societies and their movements during the year reminds me of the formation of a new one. "The Engineering and Scientific Association of Ireland," established in 1903, is ably presided over by one of our associate members, and the president-elect for the ensuing year is one of our distinguished honorary members. Though not a professional institution it is one which, in my opinion, is calculated to be of advantage to young engineers, and may, if further developed, become a valuable auxiliary to scientific education, so much needed at the present time.

Cooper's Hill Engineering College.

The decision arrived at during the present year for closing the Royal Indian Engineering College at Cooper's Hill is an event of the greatest possible interest for engineers, and deserves more than a passing notice. Many of

us can remember the circumstances under which it was brought into existence, and are aware of the mixed feelings with which its foundation was regarded. The College was established in 1871. Until that year and since 1859 the Indian Public Works Service was recruited from the ranks of young engineers by passing a competitive examination. The service afforded during that period an opening for numbers of men trained in this country, and considerable disappointment was felt when this method of selecting candidates was discontinued.

The examinations were held periodically, and "the candidates were to be not exceeding twenty-four years of age, and must have already passed three years either entirely with a practical engineer or partly thus and partly in studying engineering in a school or college recognised for this purpose."

Although the examination was comparatively easy a sufficient number of qualified candidates could not be obtained. It therefore became necessary to take special means to provide for filling up the vacancies with a supply of better educated men than those who were at that time to be found amongst the juniors of the profession.

To fulfil this object and provide a better scientific education than that afforded elsewhere this College was founded, and it was in every respect one of the most completely equipped institutions of the kind.

Reasons for Closing Cooper's Hill College.

The causes which operated to bring about its supercession are detailed in a Parliamentary paper issued this year, entitled, "Minutes of evidence taken before the Committee appointed to inquire into the expediency of maintaining the Royal Indian Engineering College and ther matters."

The proximate cause of this inquiry was the exceptional and increasing cost in maintaining the institution and in the improbability of any improvement in the financial condition of the College. In addition to the high rate of expenditure there was a large falling off in the number of students in residence; the average—about 120—being greatly below the number for which accommodation was provided. The loss would have been greater but for the amount received for testing operations carried on in the mechanical and chemical laboratories. This amount averaged about £1,170 per annum.

The falling off in the number of students appears to have arisen chiefly because of the reduced number of appointments made from the College.

Engineering Education in other Colleges.

The Committee proceeded to consider whether it would not be better to recruit the service by men who had been educated at other colleges and had afterwards gained a certain amount of experience in engineering work in this country, and with this object in view they addressed a circular letter to fifteen universities and other institutions asking for information on the following points:—

(1) The opinion of each institution as to whether there would be any difficulty in obtaining annually some 28 qualified men, of 21 to 24 years of age, for the Public Works Department, were the Royal Indian Engineering College to be no longer maintained;

(2) The number of candidates likely to come forward annually from each institution;

(3) The amount of the annual fees;

(4) The estimated cost of board and lodging, and standing subscriptions; and

(5) The duration of the course.

Dublin University was, as might be expected, asked for an expression of opinion on the above points, and as the reply given by the Registrar of the College, dated 26th June, 1903, is of more than passing interest I make no apology for reproducing the substance of it, which reads as follows:—

"I am directed by the Board of Trinity College to furnish your Committee with the following information, in reply to their enquiries:—

"Before the establishment of Cooper's Hill, when the appointments in the Public Works Department, or Woods and Forest Department, were open to public competition, candidates from this College and University were uniformly successful in obtaining a good average number of them, and the exclusion of this College from further competition has always been considered a great hardship, considering that this College is the only one, so far as known, in which the B.A. degree in Arts is required as a preliminary to a degree in engineering. Our engineering qualification has been found so high that the private railway companies in India have always been anxious to secure the services of our young men. On the occasion of the construction of the Nagpur line, connecting Bombay and Calcutta Presidencies, six of our young engineers were selected along with some 44 from Cooper's Hill, and of these six four came to the head of the list within a couple of years for efficiency, and were promoted to good posts elsewhere. We have since sent 16 to India, five to China, two to Siam, and two to the Malay Straits, and our education here has been found in every case to be just what was required to ensure success in each locality. I am further directed to say that if a steady number of appointments were guaranteed to the young engineers from this College,

we would have no difficulty in supplying from six to ten every year, fully qualified for service in India. Their ages would be from 21 to 24, though a few now ready might be taken at first up to the age of 26.

"The course for B.A. degree in this University is a four-year one, and the course in engineering goes over three years. These to a certain extent overlap, so that five years will generally cover the complete education of an engineer here. We usually advise our young men, on leaving the school, to get a year's practical training in some engineering, locomotive, or mechanical establishment, before recommending them finally for important posts at home or abroad.

"The costs of the B.A. degree, with instruction and examination in the four years' course, is £80, or £97 for five years. The fees for three years in the engineering school amount to £40. A few extra fees in special subjects may be put down at £10, so the total cost in fees in the five years may be put down as something less than £150. The cost of living inside the College varies according to the tastes and habits of the students, but £70 a year would be a fair allowance, to cover such cost, and pay for games and other college subscriptions. £100 to £120 a year should practically cover everything, cost of living, subscriptions and fees."

As the replies received from most of the other engineering schools give the duration of the courses and the cost, it will be of interest to give the following particulars, which may be useful in considering the question of the Education of Engineers. (See Appendix No. 1, p. 77.)

The three Queen's Colleges at Belfast, Cork and Galway were not included in the list of institutions applied to by the Committee. This is probably owing to their being now

classed as under the Royal University of Ireland, and as this body exercises examining functions only and is not itself an educational institution the colleges have been overlooked. Many engineers from these colleges were successful in the Indian Public Works Department prior to the establishment of Cooper's Hill in 1871, and their engineering schools will, no doubt, in the future, under the new arrangement, furnish their quota, as in the past, for the Indian Service.

The Committee having satisfied themselves of the ability of other institutions to supply suitable men, next proceeded to inquire whether the education given at Cooper's Hill is superior, from an Indian point of view, to that obtainable at other places. When it was first proposed to establish the College it was contemplated that the charge to a student would be 100 guineas annually. When the College was opened the charge was fixed at £150. After the scheme of re-organisation was decided on in 1880 this sum was raised to £180, and, taking into account other necessary expenses, the cost to students for their education and maintenance at the College amounts to £280 per annum. This sum is much higher than what is necessary at the principal engineering schools, and the Committee having ascertained that as good an education could be provided at a much less cost elsewhere, and that men as good as those who passed through Cooper's Hill could be obtained by other means, unanimously recommended the closing of the College, and proceeded to formulate the alternative method they recommended for adoption, which is quoted as follows:—

"NEW METHOD OF APPOINTMENT TO INDIAN PUBLIC WORKS SERVICE.

"It remains to state the alternative method of obtaining

and training officers for the Public Works and Forest Services, which it is expedient in our judgment to adopt.

"First, as to the recruitment of engineers. Our recommendation is that the Secretary of State should, by advertisement in the public Press, call for candidates having the following qualifications:—

(*a*) That their age does not exceed 24 years;

(*b*) That they have obtained a degree or diploma or other distinction equivalent thereto at some recognised and approved institution for engineering education;

(*c*) That they have had at least one year's subsequent experience as assistant in the preparation of the designs for, or in the execution of, some engineering work of importance;

(*d*) That they satisfy the usual requirements as to character and nationality.

"Selection should be made from the candidates in such way as the Secretary of State may think fit, but we advise that the selection should be entrusted, subject to the final approval of the Secretary of State, to an Advisory Board, of which at least one eminent representative of the engineering profession should be invited to become a member. The duty of the board would be to select the best from amongst the candidates by examining their testimonials and distinctions by personal interview, and by making such inquiries as to their history and character as might in their opinion be advisable.

"The recommendations which have been made in the foregoing paragraph apply equally to the selection of officers for appointment to the Telegraphic Department, except that these officers will be required to have spent at least one year as an Electrical Engineer or in other similar capacity.

"Candidates selected for appointment to the Public Works Department and the Telegraph Department should proceed immediately to India without undergoing any further training in this country."

In April, 1904, the Secretary of State for India intimated to the Government of India:—

"For the next three years, therefore, the new system of recruitment will come into force only for such additional appointments as it may be found necessary to make, over and above those to be filled by the men now in Cooper's Hill and those who may be selected at the next entrance examination. By the end of that period—namely, in 1908—the change of system and the opening of the Indian Public Works Service to the students of all the chief schools of engineering in the United Kingdom will have become known, and I am advised that the number of candidates will be sufficient to afford an ample field for selection."

Final Closing of the College at Cooper's Hill.

On 25th April, 1904, the Under Secretary of State for India intimated to the President of Cooper's Hill for his information and that of the professors and others at the College that, acting on the recommendation of the Committee which sat to inquire into the subject last summer, it had been decided that the College is to be closed, adding that Mr. Broderick wished it to be known that he had decided on it with much reluctance, and only after the fullest consideration of the subject, greatly regretting that the measure should have been considered necessary in the public interest.

The final stage is now reached in the attempt made by Government to administer a College for the education of Civil Engineers, and notwithstanding the advantages that will accrue to the engineering schools some will regard

with regret the failure of the undertaking, and the blotting out of the best equipped engineering college in the Empire. There is no doubt much advantage will result from the healthy rivalry amongst students of the different engineering schools in competition for the Indian Service, and in this way the high standard of professional education which was aimed at in Cooper's Hill will be fostered and maintained in those schools where students are intended as competitors for this Service.

1904—The Centenary of the Railway Locomotive.

It will be of interest to remind engineers that the present year is the centenary of the railway locomotive. Exactly one hundred years ago Richard Trevithick, a Cornish engineer, made the first steam railway locomotive. It performed a journey of nine miles in four hours, carrying ten tons of iron and 70 passengers, over the Penydarran tramway, near Merthyr Tydvil, in South Wales. The tramway was the forerunner of the railway. The total weight hauled on the occasion was 25 tons. Two years before this a high-pressure steam carriage for ordinary roads had been constructed by Trevithick, which was patented by him and his cousin Andrew Vivian in 1802. He seems at this time to have had the idea of using his engine on plates or rails, as in the specification of his patent he describes the possible use of his engine for hauling over railways as well as common roads, but it was not until 1804 that he actually carried this idea into operation. This first railway journey is said to have been the result of a wager laid by the owner of the tramway, which was then worked by horse-power only, that it would be possible to convey a load of bar iron over it by steam-power. Trevithick was at that time employed at the Penydarran Iron Works in erecting a stationary engine

for the company. He immediately set to work and constructed a locomotive which was a modification of the steam carriage made and patented by him and Vivian in 1802, and with the new engine the wager of £500 was won for his employer.

Owing to the defects in the railway track the working of the engine was not successful; the damage done to the plates was very great, and from this cause the engine was a more expensive agent than animal power. Notwithstanding this objection, Trevithick made several locomotive engines for other lines in the mining districts in Wales, and arranged for their manufacture at Gateshead for the Newcastle district. It was not, however, until Stephenson had constructed his second engine at Killingworth that the superiority of the steam locomotive over horse-power in moving heavy loads was fully established.

The Stockton and Darlington Railway opened for traffic in 1825 was the first public railway in the world, and though intended for the conveyance of minerals and goods only, it rapidly developed a considerable passenger traffic, which completed its financial success.

Owing to the comparatively slow rate of speed attained, together with the smoke, noise, and jerky motion, the locomotive had not come into general favour, and it was not until 1829 (when the Liverpool and Manchester Railway was under construction, and the directors, who were then undecided as to the use of steam, offered a prize of £500 for the best means of locomotion) that the results attained by the "Rocket" settled the question in favour of steam locomotion. Afterwards the development of the locomotive was most remarkable, and secured the general introduction of the railway system.

I had already prepared notes on Registration and the

Education of the Civil Engineer when I was requested by the Council to say something about the works we saw in Belfast, and, as there is not time for all, I propose to postpone the notes on the Registration and Education questions.

ENGINEERING WORKS VISITED IN BELFAST IN 1904.

The City of Belfast ranks third as the most important commercial centre in the United Kingdom. The revenues collected by the authorities amount to over £3,000,000 per annum, a sum only exceeded by London and Liverpool. It is the chief manufacturing and commercial city in Ireland, and the most progressive. The chief industries, in addition to the linen manufacture, are ship-building, distilling, pork-curing, aërated water manufacture, artificial manures, rope and cordage making, and the manufacture of tobacco—all of which are carried out on a large scale.

One of the most remarkable features of Belfast is the rapid and astonishing progress made in its prosperity. This is seen in many ways. For instance, the valuation in 1894 was £770,726, and at the end of the present year it has risen to about a million and a half, or nearly double what it was ten years ago. This is partially accounted for by the large extension of the city boundaries effected in 1895, and is partly the result of the revised valuation of the city by the Commissioner of Valuation, now approaching completion.

The most valuable test of the progress of any place is in the amount of postal business transacted. For some years past the increased amount of work done by the local post office, and the increased revenue therefrom, has been at the rate of 10 per cent. per annum. In less than ten years the work and revenue have doubled, and as a consequence the postal accommodation has to be increased to keep pace with the work.

Although the Corporation of the City of Belfast have expended very large sums in improvements the total rate levied by them is only 6s. 6d. in the pound, including the penny rate for technical instruction. The total indebtedness of the city is—

For Sanitary Loans	-	£1,589,056
Under Local Acts	-	559,350
Total	-	£2,148,406

They have borrowing powers for twice the amount of the annual valuation, which at the last return was £1,251,805, but will be about a million and a half at the end of the year.

The gas works are owned by the Corporation. The price charged for gas is 2s. 3d. per thousand cubic feet. When electric lighting came into general use, although the city owned the gas works, it proceeded to introduce the electric light also, and erected an installation at a cost of about £275,000, and as an instance of successful municipal trading some figures relative to this enterprise may be given. The gross income from the electric light undertaking for the year ended 31st March last amounted to £27,532 6s. 3d. The cost of generation and supply was £10,008 11s. 9d., leaving £17,523 14s. 6d. Out of this amount £11,586 2s. 4d. was paid for interest and sinking fund, and after adding some small items of income the sum of £6,348 7s. 8d. remained to credit of net revenue. The current is produced at a little over 2d. per unit. The price per unit for electric current for general lighting purposes is 6d. for the first hour of the maximum consumption and 1¾d. afterwards. There is an arrangement by which it is supplied to private houses at a flat rate of 4d. per unit. The price of current for power is 2½d. for first hour of maximum consumption and 1d. per unit afterwards. The total income

of the Corporation for the year (apart from the gas undertaking) was £598,514 4s. 4d.

Encouraged no doubt by the success of their gas and electrical undertakings, the Corporation are about to purchase the entire tramway system and to extend it at a cost of about a million and a quarter. The tramways are at present worked by horse-power, and it is proposed to spend £85,000 on the extension of the electric generating station to provide the current necessary to work the whole tramway system. The entire lines at present owned by the company will be relaid with new rails; the present gauge of 3 feet 4½ inches will be adhered to, and overhead trolleys will be adopted. The estimated cost of the work, including rolling stock and the extension of the generating station, is £827,000, to which has to be added the cost of purchase of the present lines. An abstract of the report of the City Surveyor and the City Electrical Engineer, with their estimates, was published in "The Irish Engineering Review" for August last.

The Port, Harbour, and Graving Dock of Belfast.

The Harbour Commissioners are elected by ratepayers of £20 valuation and ship-owners of 50 tons shipping. The quays extend from the Queen's Bridge on both sides of the river, for about one mile, and the total quay space is 24,860 lineal feet. The area of the docks and basins is about 43 acres. The depth at low water is about 20 feet. At Alexandra Wharf and Jetty there are deep water berths dredged to a depth of 26 feet at ordinary low water. A new straight channel has been dredged from the Victoria Channel to deep water. There are four graving docks, the largest of which is 800 feet in length, with an entrance of 80 feet. The crane accommodation is extensive, the largest being capable of lifting 100 tons. The

revenue of the trust in 1903 was £156,947, and the expenditure £135,726. The tonnage which cleared from the port in 1903 was 2,435,908 tons. The total indebtedness of the Harbour Commissioners at end of 1903 was £1,364,264. The Harbour Commissioners' tramways connect the quays with the various railways—viz., the Great Northern of Ireland, the Belfast and Co. Down Railway, and the Northern Counties Railway, which is now taken over and worked by the Midland Railway Co. of England. The Lagan Navigation Canal connects the port with Lough Neagh.

The new graving dock, now in course of construction, is situated near the Alexandra Graving Dock, on the County Down side of the Victoria Channel, immediately behind, and parallel to, the Clarence Wharf.

The principal dimensions of the dock are as follow:—The length of the dock on the floor, from the north quoin of the inner caisson sill to the toe of the battered wall at the south end of the dock is 850 feet; or, if the caisson be placed in its outer berth, the length is 886 feet. The breadth of the dock, from toe to toe of the battered side walls below the altar courses, is 100 feet; the breadth of the dock from coping to coping is 128 feet. The depth of the surface of the floor of the dock, at centre, below harbour datum (which is 1 foot $8\frac{3}{4}$ inches below average low water line) is 26 feet 6 inches; the height of the coping above the harbour datum is 16 feet. The depth of the floor surface, below the coping, at the centre of the dock, is 42 feet 6 inches; width of caisson chamber, in clear, 23 feet $4\frac{1}{2}$ inches.

The dock floor falls 12 inches on each side of the centre line towards open drains at the sides of the dock—no longitudinal fall being given. The level of the surface of the inner and outer sills at the centre is 40 feet 6 inches

below coping line, or 24 feet 6 inches below the harbour datum. The level of the surface of the concrete apron, northward of the outer sill, is 43 feet 6 inches below the coping level, or 27 feet 3 inches below the harbour datum. The level of the upper surface of the brickwork invert of the caisson chamber, and caisson track, in the centre, is 45 feet 3 inches below the coping level, or 29 feet 3 inches below the harbour datum.

The materials of which the graving dock will be constructed are mainly concrete, brickwork, and granite work—the facework of the walls and altar courses, floor, and coping being of a superior class of concrete work. The facework of the side walls of the entrance to the dock, together with the sills, caisson quoins, &c., is to be of granite work.

As an additional precaution against the possibility of water finding its way into the dock from the surrounding sandy strata an invert of brickwork, 4 feet 6 inches in thickness, running quite across the dock, and for its entire length, is being built between two layers of concrete; and brick side walls are also being carried up at the back of the dock side walls to the level of 4 feet above harbour datum. All the brickwork is built with Portland cement mortar of the proportions of one part cement to two of sand.

Some idea may be formed of the magnitude of the work when a few items in the quantities of materials to be used are taken into consideration. The total quantity of concrete will amount to about 112,063 cubic yards; the brickwork to about 35,788 cubic yards; and the granite ashlar work to about 51,890 cubic feet. The quantity of excavations to be removed will amount to about 429,392 cubic yards.

The pumping appliances for the new dock are of an

extensive character, consisting of three centrifugal pumps, each having two suction pipes of 54 inches diameter, and a discharge pipe 60 inches in diameter—the pump discs being 7 feet 6 inches in diameter. The engines are to be of the compound, non-condensing type, the three developing a power of about 3,000 I.H.P., running at the rate of 150 revolutions per minute. The boilers will be four in number, of the marine tubular type, capable of supplying 64,000 pounds of steam per hour—the working pressure being 200 pounds per square inch.

The pumping plant is so designed that the graving dock can be emptied within the space of 100 minutes—the water standing at commencement of pumping operations at a level of 10 feet 8½ inches above harbour datum, or at average spring tide level—and the quantity of water to be removed amounts to about 21 millions of gallons.

The entrance to the graving dock will be closed with a travelling caisson, provided with a folding bridge or roadway—the caisson, when the dock is open, running into a recess chamber at one of the entrance side walls. A hydraulic installation is to be provided for the opening and closing of the entrance by the travelling caisson, and for lifting and lowering of the heavy penstock, or sluice doors, and for working five capstans—three of 10 tons' and two of five tons' capacity.

The contract for the dock was given to the firm of Messrs. Walter Scott & Middleton, Ltd., of London; the pumping plant contract to Messrs. Andrew Barclay, Sons & Co., Ltd., of Kilmarnock; and the caisson contract to Messrs. Hannah, Donald & Wilson, of Paisley. The period within which the dock has to be completed and handed over by the contractors is three years and four months from the date of the commencement, which was

the 14th October, 1903. When completed it will be the largest in the world for sectional capacity.

The Engineer-in-Chief for the new graving dock is George F. L. Giles, Esq., M.Inst.C.E., Engineer to the Belfast Harbour Commissioners, and the approximate cost of the entire works in connection with the contract is placed at about £320,000.

Shipbuilding Works.

There are two iron shipbuilding yards in Belfast—those of Messrs. Harland & Wolff and Messrs. Workman, Clark & Co. The former works were visited by the members in June last. They contain, with the Marine Engineering Works attached, an area of nearly 80 acres, and upwards of 12,000 hands are employed. These works are the most extensive of the kind in the world, and from them have been launched the largest steamers afloat. Since 1861 the fleet of the White Star Line of mail steamers, including the "Oceanic," "Celtic," "Cedric," and "Baltic," were built here.

These yards are on the Admiralty lists as suitable for building ships for the Royal Navy.

As indicating the extent of the shipbuilding industry in Belfast it may be noted that according to Lloyd's Register Shipbuilding Returns for the quarter ended 30th September last there were on that date 18 steamers with a gross tonnage of 163,010 under construction in Belfast, as against 18 with a gross tonnage of 163,095 on the corresponding date in 1903.

The first turbine Atlantic liner—the "Victorian"—was launched from the shipbuilding yards of Messrs. Workman, Clark & Co. during the present year, and was built for the Allan Line. This vessel is 540 feet long, 60 feet broad, depth 40 feet 6 inches. The steam is generated

by 8 boilers; a high pressure and two low pressure turbines drive the three propellers.

Although the "Baltic" is the largest vessel yet constructed, the "Oceanic," built in 1899—at the launching of which I had the privilege of being present—seems to have attracted more attention. The latter vessel was the largest when built, and measured 704 feet in length, extreme breadth 68 feet 4½ inches, depth 49 feet, with a draught of 22 feet. A double bottom, 5 feet 1 inch in depth extends the full length of the ship, divided into nine compartments. There are five steel decks and thirteen watertight bulkheads. The saloon measures 80 feet by 64 feet. The horse-power of the "Oceanic" is 28,000.

The "Celtic," built in 1901, is a vessel of larger carrying capacity, with a gross tonnage of 20,900 as against 17,300 of the "Oceanic." The "Celtic" is 700 feet long, breadth 75 feet, horse-power 13,000, and has accommodation for 2,859 passengers, which is about 1,000 more than the "Oceanic" carries. The increased space is for third-class passengers.

Another vessel—a sister ship, named the "Cedric"—has been built on the same lines as the "Celtic," and of the same dimensions and capacity.

The "Baltic" made her maiden voyage early in July this year. She is the largest vessel afloat, and measures 726 feet long and 75 feet wide, with a carrying capacity of 28,000 tons. There are two sets of quadruple expansion engines. The high-pressure cylinders are 33 inches in diameter; first medium cylinders, 47½ inches; second medium cylinders 68½ inches; and the low-pressure cylinders 98 inches in diameter; stroke 63 inches. There are eight boilers, each 15½ feet diameter and 19 feet long. Speed 17½ knots. The "Baltic" carries 3,000 passengers,

with a crew of 350. The desideratum here was comfort combined with speed.

It is not likely that any vessel of larger draught will be built here, at least not until the Channel is deepened.

The shipbuilding industry in Belfast is of comparatively recent growth. The late Sir Edward Harland, who was the founder of the present firm of Harland & Wolff, was manager of a small yard in the Queen's Island, the ownership of which he acquired in 1859, and in 1861 entered into partnership with Mr. Gustavus Wolff, and it was at this period that the firm commenced to build for the fleet of the White Star Line. In 1874 the Right Hon. W. J. Pirrie became a partner, and he is at present head of the firm.

The works which we were shown over by the manager, Mr. Carlisle, are self-contained; the designing and equipment throughout, including the engines, boilers, joinery, cabinet work, and upholstery, are all executed on the premises.

The first place visited was the drawing office, where the designs are prepared. There large scale models of one half of the ship are made, and from the model the working drawings are got out in the office for the different departments. The moulding loft was next entered, on the immense floor of which the lines of the different parts of the projected vessel are laid down full size, afterwards to be transferred to scrieve boards in the frame shed, from which the plates are shaped, and the steel frames prepared in the platers' shops and other departments.

The foundry, forge, erecting shop, moulding and turning shops were visited, where the engines and boilers and the machinery for propelling the vessels were being made. It was observed that the boilers were a combination of the cylindrical and water-tube construction.

The vessels on the slips were next examined, also the travelling gantrys which enabled the hydraulic and pneumatic riveters to be used. The joiners' shop (where the only representatives of the old ship carpenter of the days of wooden ships are to be found) was visited; the fittings here are transferred into the ship when the plates of the hull are staunched, and after the launch the engines, boilers, bases, &c., are taken down in the shops and placed in their final position on board. The slides exhibited show the operations carried on in the different places visited.

In the North yard there are three travelling gantries and four slips for very large vessels, which are launched down the river. In the South yard the vessels are launched into the Abercorn basin, except from the outside slip, where the boats are launched up the river. As the space is curtailed, the boats are pulled smartly up by anchors buried in the earth covered with masses of heavy iron cable.

In addition to the three gantries, each 100 feet high and 95 feet wide, there is another large gantry, 180 feet high, 230 feet broad over all, and 600 feet in length, in course of erection in the yard. It is being constructed for the firm by the Brown Hoisting Machinery Company of America, and will not be completed for some time yet.

A new electrical generating station has just been erected for the firm. The whole of the machinery in the works will eventually be driven by electric power.

The weekly wages paid for the 12,000 men employed in the works is over £20,000. The works are regarded as the greatest shipbuilding and engineering establishment in the world.

Belfast Water Supply.

The city is provided with water by the Belfast Water

Commissioners—a body incorporated in 1840, in which year the population was only 75,308. Prior to that date the town was supplied from springs on the Malone-road, led into tanks, and drawn off through wooden pipes by means of fountains. The new works on the Antrim-road, authorised by the Act, were carried out at a cost of £66,000. There were three basins with a capacity of 150 million gallons which served the town until 1865, when another Act was obtained, and certain reservoirs at Woodburn, near Carrickfergus, with a conduit into Belfast, were constructed at a cost of about £150,000, giving an available supply averaging 3½ million gallons per day. The population had then reached a total of 120,000 persons.

The extraordinary growth of Belfast necessitated frequent extensions of the works, and in 1874, and again in 1879, Parliamentary powers were obtained for borrowing purposes to increase the supply, and seven large storage reservoirs were constructed near Carrickfergus containing 1,500 million gallons. The total expenditure authorised under the Acts from 1840 to 1879 amounted to £500,000.

As the town still extended another Act was obtained in 1884, when the population had reached 223,000, and the demand for water for trade purposes was increasing. Works were carried out at Stoneyford, at a cost of £170,000, comprising two reservoirs with a capacity of 900 million gallons, which, when completed, together with the former works, provided a total supply of 11½ million gallons per day in a year of average rainfall. Up to this time the water was not filtered, and suspicion having been cast on the character of the water, it was found desirable to undertake its filtration, and to effect this 13 filter basins were constructed at a cost of about £97,500.

But the city was still progressing, and the Water Commissioners were face to face with a possible water famine in a few years, and, to avert this, steps were taken seeking to supplement the works. After an exhaustive examination of all the possible sources of water supply within fifty miles of Belfast the southern catchment of the Mourne Mountains was selected for the new supply, and in 1893 an Act was obtained for this scheme. The catchment area over which the Water Commissioners obtained rights are about 9,000 acres in extent, consisting of mountain slopes and boulder-covered moorland. Two of the principal rivers draining the water sheds are the Kilkeel and Annalong streams. There are other catchments which could be acquired if necessary, but what is already acquired is calculated to produce about 20 million gallons per day in addition to the former supply of 11½ million gallons per day for a population of 370,000 persons.

The scheme provides for the construction of two large storage reservoirs, but in order to avoid a large expenditure within a few years, and to spread it over a period of seven or eight years, and limiting it to about £100,000 per annum, the main aqueduct and service reservoir only were put in hands, and these have been successfully completed. The aqueduct from Kilkeel Valley to Knockbracken service reservoir is 35 miles in length, and from the service reservoir to Belfast is 7 miles There are 6½ miles of tunnelling in three lengths, and 15¾ miles concrete culvert in cut and cover trench, where the depth did not exceed 30 feet. The remaining 12¾ miles are formed of cast iron pipes 36 inches in diameter, but where pressure is great mild steel-plate pipes were adopted.

A portion of the tunnelling was formed through impervious rock without any lining. Where the rock was porous a lining of concrete was adopted, as shown on the

different sections. Considerable trouble was experienced where the tunnel passed through loose sandy earth. It became necessary to line it with cast iron pipes 6 feet in diameter, having flanged joints inside. A shield and compressed air was used for getting this lining in. The invert was levelled with concrete to the height of the flanges, and in some places cement grouting was forced into the spaces left vacant between the iron lining and the surrounding earth.

The *Irish Builder and Engineer* of 31st December last contains a description of the tunnelling portion of the Belfast Waterworks Extension.

Where the line of conduit ran through soft ground a foundation of dry stone filling was constructed when the depth did not exceed 10 feet. A portion, of about 400 yards in length, where the depth was greater, was supported on timber piling up to 24 feet, with a staging on top formed of concrete on steel joists, on which the conduit was built.

The service reservoir at Knockbreckan holds about 100 million gallons of water, and for the past three years it has been supplying the Co. Down side of the city. The scheme has only been developed in part, but it has been done in such a way as to give immediate relief.

The two storage reservoirs are yet to be built. The supply is at present taken from the Annalong and Kilkeel rivers direct. As regards the main aqueduct, the tunnels and cut and covered culverts are made full size to carry 30 million gallons per day, but the iron piping is only laid to bring in the first instalment of 10 million gallons per day.

It has been found necessary to change the position of the proposed reservoir in the Kilkeel Valley by placing it lower down, where the same storage capacity can be

obtained with a less costly embankment. There is here a glacial moraine to be excavated for forming the embankment. This moraine is composed largely of felspathic earth, which, like all mountain *débris* caused by erosion, is fairly tenacious. The total estimated expenditure of the Mourne scheme is £1,250,000, of which £700,000 has been already spent.

Another feature of importance in connection with the Belfast Waterworks is the purchase by the Commissioners of the gathering grounds at Woodburn and Stoneyford.

Owing to an outbreak of typhoid within the catchment area and the position taken up by the Corporation that much of the typhoid prevalent in Belfast was due to disease germs brought in by the water, the Belfast Water Commissioners proceeded to acquire by compulsory purchase the more closely-populated portion of the catchments at Woodburn and Stoneyford at a cost of about £200,000, and for this purpose an Act was obtained in 1899 to clear the area of human habitations, a course which the Water Commissioners are to be commended for following.

The capital expenditure of the Water Board to 31st October, 1903, amounted to £1,880,714 7s. 9d. The total outlay in the year from capital was £44,488 19s. 6d., and from reserve £91,172 5s. 9d., making a total of £135,661 5s. 3d.

In the Belfast Water Act of 1903 the Board obtained powers to postpone for a period of ten years the payments to be made to the sinking fund in respect of certain of their borrowing powers.

The water-rate for domestic purposes is 1s. 4d. per pound on the valuation. A deduction of 25 per cent. is

made in the water-rate in dwellinghouses of £8 valuation and under.

The Chief Engineer to the Belfast Water Commissioners is Mr. Luke Livingstone Macassey, M.Inst.C.E., B.L., &c., and to him I am indebted for a loan of some drawings and slides illustrative of this important work.

The Sirocco Engineering Works.

The visit paid to the Sirocco Engineering Works—brought into existence in 1881 for the manufacture of the inventions of the founder, Mr. S. C. Davidson—was most interesting. These inventions were at first confined to mechanical contrivances for the preparation of tea-leaf for the market, including drying, rolling, sorting, and packing, so that the whole manufacture of tea—from the green leaf stage to shipment—is accomplished by machinery made here.

Arising out of the tea-drying process the Sirocco ventilation fans were invented and came into use. The firm has a world-wide reputation for these ventilating appliances, and at the time of our visit we saw a large consignment about to be despatched to the Admiralty Dockyards for the Royal Navy.

A large number of motor-driven fans were made here for the SS. "Celtic." They are used largely by the mercantile marine and in vessels for foreign Governments. The principal kinds are the motor-driven centrifugal fans with adjustable discharge, the engine-driven Sirocco fan, and the motor and belt-driven propeller fans.

They have also been most successful for induced draft in boilers, enabling cheaper qualities of coal to be used. The 85-inch diameter cased fan for an induced draft installation has given good results. The forced draft for

boilers has been employed by Mr. Davidson in connection with his patent furnace fronts and patent fire-boxes.

The fans are also used in connection with the pneumatic conveyance of material, such as tea or tobacco leaf, grain, &c. The material is fed into a hopper, and is carried by the air blast through a delivery pipe to its destination irrespective of the distance to be carried.

The Sirocco patent air filter has webs of fibrous material over the drum of the fan in contact with steam or refrigerating fluid for filtering, humidifying, or cooling the air which is drawn through the filtering screen by the fan, and the air is conveyed by pipes where required.

We had not time to visit the Belfast Ropeworks, which are known to be the largest in the world. The company manufacture all descriptions of rope and twine, "from the largest cable for an Atlantic steamer down to the finest fishing line, of which 60 fathoms weigh only an ounce."

The Engineering School, Queen's College, Belfast.

To Belfast was allotted one of the three Queen's Colleges established in 1845. The buildings were designed by Mr. (afterwards Sir Charles) Lanyon, who was a member of this Institution, and its first honorary secretary. It was opened in 1849, and its erection cost £34,357. The original design comprised a frontage of 300 feet, with two wings of a depth of 150 feet, forming three sides of a rectangle. It has been extensively added to since. Macaulay, the historian, declared that it is "worthy to stand in the High street of Oxford." It is a fine specimen of the Tudor treatment of Gothic. The examination hall has a fine oaken hammer beam roof.

An additional medical block was added to the rear, and new chemical buildings, with biological and pathological laboratories, have been added to the south wing. An

engineering drawing room was added in 1864. A new Engineering and Physics Laboratory is in course of erection, and when completed will be one of the best-equipped of its kind in the Kingdom.

The new Library—a detached building in severe French Gothic—was designed by Mr. Lanyon in such a style and position as should not detract from the effect of the main structure. The Students' Union Buildings were erected in the north-east angle of the grounds in 1899 at a cost of about £6,000.

Professor Godwin was the first occupant of the chair of Civil Engineering. He was in practice, and held the position of engineer to the then Ulster Railway Co., and also to the Belfast and Co. Down Railway Co. He resigned in 1857, when he was succeeded by Professor James Thompson, LL.D., D.Sc., also a practising engineer of much eminence, as well as a profound mathematical scholar. He resigned in 1873 to take the chair of Engineering in Glasgow University. Professor Fuller was in office from that year until 1884, when the present occupant of the chair, Professor Fitzgerald, B.A., A.M.I.C.E., was appointed. The Queen's College, Belfast, was fortunate in having many eminent men as professors, amongst whom may be mentioned as being more intimately connected with the Engineering Schools the names of Thomas Andrews, Professor of Chemistry, and John Purser, Professor of Mathematics. Of the numerous students who have passed through the Engineering Schools many have acquitted themselves in a highly creditable manner, both at home and abroad, where they have filled distinguished positions.

Municipal Technical Institute.

Another educational institution, well worthy of a passing notice as affecting the acquisition of engineering

knowledge, is the new Municipal Technical Institute, now well advanced to completion. The total cost of the structure will be about £100,000, exclusive of equipment, furnishing, lighting and heating. The building is five storeys in height, and provides for a net floor area of rooms of 109,000 superficial feet. The Corporation levy a penny rate, which produces about £4,500 per annum, and the Department of Agriculture and Technical Instruction supplement this by an annual payment of about £11,000. There are other sources of income to be added to this, such as fees for science and art claims, interest on sums invested, making a total income last year of about £20,012. After paying all expenses the Committee have been able to accumulate a sum of £31,287 towards the expenses of equipment, &c., already mentioned.

The number of students on the roll for the present Session is 4,658, who pay fees amounting to over £1,500. A programme is in operation embodying instruction in the following amongst other departments—viz., Mathematics, mechanical and electrical engineering, naval architecture, the building trades, pure and applied chemistry, and natural science. A professional expert has been placed at the head of the mechanical engineering department, and it is intended to have a skilled naval architect to look after the department of naval architecture.

The second day of our visit included a pleasant excursion, under the guidance of Mr. Wise, along the Antrim coast as far as Islandmagee, near Larne, and over the famed Gobbin's Path, which opens up views of delightful scenery between cliff and wave.

This path was constructed by the railway company to enable tourists to visit the well-known Gobbin's Cliffs in Islandmagee. They are reached from Ballycarry station,

the distance being one mile to the commencement of the under-cliff section. The under-cliff section is about a mile and a half long, and leads up to the cliff section, of which about three-quarters of a mile has been constructed. There are no constructional details of any interest on the under-cliff section, but the cliff section has necessitated a large number of bridges, varying from ten to thirty feet span, formed of two rolled steel joists, from 15 inches by 6 inches to 12 inches by 5 inches, varying in depth according to the span. Flooring 9 inches by 1½ inches is let in, resting on the lower flange, and the whole is finished with a hand-rail of cast iron standards and 1 inch galvanised iron piping bolted to the top. About mid-way in the cliff-section an isolated sea stack occurs, known locally as "The Man-o'-War," separated from the mainland by a chasm 65 feet wide at the path level. To span this a special bridge—known as "Goban's Bridge" was designed by Mr. Wise. The steel framework is 70 feet in length, and is composed of longitudinal angles and bars, with 12 elliptical stiffeners.

The ellipses are made of 3 inch by 3 inch by ⅜ inch angles, major axis 7 feet inside, minor axis 4 feet 6 inches, spaced 7 feet 3 inch centres, except the bay at each end, which is 2 feet 3 inch centres. The longitudinal members are six angles 3 inches by 3 inches by ⅜ inch, and six bars 3 inches by ½ inch. For additional bearing surface at the joints, the bars and two top angles are riveted to strengthening plates 10 inches by 10 inches by ⅜ inch at each ellipse. The diagonals are bars 3 inches by ½ inch. All joints are butted, and have cover plates. The floor is composed of two 12 inch by 3 inch pitch pine planks, bolted on to floor brackets on each ellipse. Owing to lack of space and heavy seas it was found impossible to erect the bridge at the site, and

it became necessary to erect it in the permanent way yard at Belfast, where it was transferred on board a scow, towed down to the Gobbins, and hoisted into position with derricks. It was originally intended to stay the bridge with wire rope guys, but on erection it proved sufficiently stiff to enable these to be dispensed with. About 200 yards above this bridge the path is carried on to a smaller sea stack by two of the standard bridges, and it then takes a bend round a small bay to the mouth of the "Windy" Cave, into which the path descends about ten feet by a wooden staircase. The floor of this cave is below the level of the sea outside at high tide, and the caretaker has to keep it drained by means of a pipe inserted in one of the dams at the entrance. At the further end of this cave the path mounts up to a considerably higher level by a couple of wooden staircases outside—the rise being about 30 feet. After passing across the entrance to the "Spleenwort" Cave the path is carried by stone steps into the "Otter" Cave. This cave when discovered was largely choked up with *débris*, and while the men employed at the work were clearing it out many interesting discoveries were made, including antlers of the red deer, skulls of otters, and bones of other mammalia. An exit was made through the rock from this cave, and the path was carried on about 300 yards to the edge of a large inlet with a cave at the end, where the path at present terminates—the intention being to cross this gap with a large suspension bridge of about 73 feet span.

The First Electric Tramway.

On the third and last day of the excursion our members had the advantage of seeing the first electric tramway constructed in the United Kingdom. This line was opened in 1883. It runs from the railway station at Port-

rush along the coast road for a distance of 8 miles to the Giants' Causeway. Where it passes through the streets of Portrush it is laid with grooved rails and paved; for the rest of the distance the rails are laid on a slightly raised path, protected from the roadway by granite curbing. The line is single, and is on the 3 feet gauge, with Bessemer steel flange rails of 42 lbs. to the yard—the head of the rails being level with the ground. The gradients are heavy, and are in parts as steep as 1 in 30, and the curves are in many cases sharp. The promoters and principal shareholders of the line are Dr. Traill, Provost of Trinity College, Dublin, and his brother, Mr. William A. Traill, who acted as engineer and carried out the construction of the works without the intervention of a contractor.

Under the Act of Parliament obtained by the promoters electricity or any other mechanical power could be used, and as water-power, with a head of 25 feet, was available from the River Bush at Bushmills, two powerful 27-inch Allcott turbines were erected, which together give a total of 100 horse-power to work the dynamos for producing the necessary current.

An attempt was made at first to convey the current by means of the ordinary rails insulated in asphalt and copper-fastened. This was not found satisfactory, and it became necessary to make the insulation more complete. To accomplish this a third rail was fixed about 18 inches above the ground, insulated on wooden posts, close to the fence. This system was worked for many years, but accidents to cattle occurred occasionally, and a cyclist who fell on the electric rail was killed. To avoid a recurrence of similar accidents the overhead trolley system, which is now in use, was substituted. Steam is used for the conveyance of the goods and mineral traffic.

The visit to Portrush, Bushmills, and the Giants'

Causeway, followed by the return journey to Belfast in special carriages provided for the party by the Midland Railway Company through Mr. Wise, completes the programme drawn up by him for our entertainment, for the successful carrying out of which the formal thanks of the Council and of the Institution have been conveyed to him in an appreciative manner.

APPENDIX No. 1 TO ADDRESS OF PRESIDENT.

Cost and Particulars of Engineering Education at the Universities.

At Cambridge University the duration of the course is normally three years. A fourth or post-graduate year could readily be added, with provision in it for special teaching adapted to Indian service requirements. As to cost, the annual fees of a student taking a full engineering course amount £25 or £30. The estimated cost of board, lodging, &c., is from £150 to £200, according to the college which the student joins, but still more according to the student's tastes. It would be possible by the practice of strict economy to reduce the expenditure below £150.

At University College, London, the fees for the normal three years' course in the engineering department amount to 115 guineas, being an entrance fee of 10 guineas and an annual payment of 35 guineas for each of the three years. The college does not provide residence for students; they make their own arrangements, and the cost of board and lodging is therefore the same as for other young men of the same class living in London. As to standing subscriptions, it is desirable that all students of the college should join the Students' Union Society, subscription £4 4s. for three years, and engineering students find it an advantage to belong to the Engineering Society, annual subscription 2s. 6d.

At King's College, London, the average cost, including tools, books, &c., is placed at £60 a year. The estimated cost of board and lodging outside the college would be 30s. to £2 a week. The college is non-residential. The course for civil engineers is three years.

At the City and Guilds of London Institute the cost of education during the three years' course is annually—Fees, £30; books and apparatus, £7; board and lodging, about £70 to £100; subscriptions, very small, about £2.

At Owens College, Manchester, the annual fees for college instruction amount to about £24 for the first year,

£23 for the second, and £22 for the third year. The fees at Dalton Hall for board and lodging are £90, and at Hulme Hall £60 per session. Private lodgings would cost somewhat less than in London. The regular course for a degree or a certificate extends over three years. For the degree a preliminary examination of a general character is insisted on. The year is divided into three terms averaging about eleven weeks each.

At University College, Liverpool, the annual fees in the engineering department are £35 a year. The majority of students live with relations or friends, and comparatively few of them are in lodgings. The amount of personal expenses as distinct from college fees varies considerably with the means and the requirements of the individual student. The normal expenditure under this head is from 22s. to 30s. a week during term time. The duration of the course is three years.

At Birmingham University the courses in civil or mechanical engineering extend over a period of four years. The amount of the fees, including examination fees, is about £35 per annum. There is no residence at the University, but it is not difficult to get lodgings in suitable quarters at from one guinea per week upwards.

At the University of Durham the total fees for a curriculum in mechanical engineering would amount to £64, for civil engineering £72. The estimated cost of a student for board and lodging in the college hostel for the whole session would amount to about £54 per annum. The course lasts three years.

At the University of Edinburgh the course of instruction required for the B.Sc. degree extends over three winter sessions and one, or it may be two, summer sessions. The fees would not exceed £25 a year. As to the cost of board and lodging, much would depend on the means and habits of the student. Some would live at home or with friends, others coming from a distance would live in lodgings or board in families, and for these the charge might vary from 26s. to 30s. per week.

At the University of Glasgow the annual fees are very low. The total depends to some extent upon the classes chosen by students, but about £50 will cover the whole of the fees for a three years' course, or say under £20 a year. It is difficult to state the cost of board and lodging, as the men do not reside in the college. Probably something like

25s. to 30s. a week would provide suitable board and lodging. Full course is taken in three or four sessions, depending upon the state of preparation of the candidate on entrance. A session lasts only for six months, and students go into works or offices during the summer half-year, thus working their course upon what is called the "sandwich system," which is now meeting with so much approval from those who have been discussing the training of engineers at the various meetings held recently in London.

At the University of Dundee the cost of an engineering education for the graduating student is as follows:—The fees, including matriculation, generally amount to no more than £25 to £30 per annum for the average of the three years; while the cost of board and residence in the town, during term times, may be taken as varying from £35 to £50 per annum.

[4th January, 1905.]

MR. ROBERT COCHRANE, I.S.O., President, in the Chair.

The following candidate was balloted for and duly elected:—

WILLIAM MURPHY, as an Associate Member.

RECENT WORKS OF SEA DEFENCE AT PENZANCE.

By FRANK LATHAM, Member.

GENERAL.

SEA-COAST protection, the author believes, is a subject of growing importance to the Engineering Profession and to the country generally. The fact is apparent that in every sea-bound country nature in some places is eroding the shores, and in others is building up new land from the depths of the ocean. Valuable land and shores must suffer, unless some artificial means are provided to check the destructive action of the sea, and to assist it in depositing whatever material it holds in suspension in such suitable positions as to form barriers of shingle and sand for the protection of the coast. The works necessary for this purpose must necessarily be of a costly character, and the subject, being a wide one, must demand a great deal of individual observation and research. It is therefore in the interest of engineering and of the country generally that information should be recorded by those in charge of works on the sea-coast, who must gain some useful practical knowledge in their every-day association with this important branch of their profession.

The author's knowledge of the works of sea defence at Margate has not only included the period of the abnormally destructive seas which did so much damage to the coast and

sea-walls of that neighbourhood in 1897, but has since been considerably augmented during the time he has had charge of the harbour and other sea-walls and defences at Penzance. Here the portions of the coast which face west, extending northwards from the Lizard and around the Land's End, are subjected to the most destructive forces, owing both to the weight of the incoming seas during gales and to the erosive action of currents during calms. The effect of an Atlantic gale, with the attendant swell and oscillation of a wide and deep sea, is felt for days together after the wind has subsided. The weighty violence of such a disturbance is almost incredible, and it is certain that its searching attacks will ultimately ravage, as their prey, all structures which ineffectually oppose their impact.

The first thing to be studied in connection with any work of sea defence is the geological formation of the ocean bed and shores, the neglect of which in certain places would undoubtedly mean failure. Investigations requiring the utmost care are those pertaining to beach travel, the principal direction in which it takes place, and the estimated quantity of material travelling. The latter depends upon the formation of the ocean bed, whether productive of shingle, whether subject to much or little erosion; also the extent of travel, and whether or not material may be drifting from distant geological formations. A further consideration is the direction of the wave attack. For the position of groynes this is most important, as also in planning sea-walls and all other protective works. It will always be found that any particular part of the coast will be beaten with greater violence by the waves coming from one point of the compass than from another. Prevailing winds call for a great deal of consideration in dealing with sea-coast protection.

Mount's Bay.—The geological formation of Mount's Bay is highly interesting and instructive to engineers engaged in

coast works. The original formation of the ocean bed was slaty rock, locally known as killas, which was generally disturbed during the period of upheaval. It is now associated with a variety of other rock formations. Immediately in front of Penzance there is killas, with beds of greenstone, dykes of elvan, and a cross-course. The greenstone is a hard, granular, crystalline trap rock, the result of metamorphic action on the killas during upheaval. Along the range of greenstone rock there exist elvan dykes. The elvan or porphyry being an igneous rock, and very durable, remains protruding above the greenstone after the latter has been eroded away. The killas is more affected by erosion than either the greenstone or the elvan. Passing through all these formations, and intersecting them at right-angles, runs a cross-course or chasm of about fifty feet in width, filled with non-durable material. It forms an open channel of greater depth than the rocks it intersects, and through it the full force of the sea is directed against the sea-wall at Penzance.

Around the Land's End the depth of water at the coast-line is about 35 fathoms. The sea coming in from the Atlantic Ocean becomes divided at the Land's End, passing into the English Channel on the south side and the Bristol Channel on the north. The prevalent winds, being from the west, accelerate the passage of the tidal wave from the Atlantic, whereby all the shingle which makes up the Cornish beaches is driven in an easterly direction. Instances of this action may be seen in many places round the coast, especially at the Looe Pool, near Porthleven, where, owing to its natural protection from the western scour, the accumulation of shingle is so great that a natural bar has been thrown up, shutting out the sea, and forming a lake of fresh water on the inland side.

It is generally admitted by geologists that the sedimentary rocks, which formed the bed of the ocean at the time of the

granite consolidation, were lifted by volcanic upheaval and eroded by the sea. The metamorphic rocks must also, to a great extent, have been eroded by the sea; and the combined material has gone to make banks of sand and shingle in the two channels.

Groynes.—Judging from the foregoing data, the probability of rapidly "warping up" a beach at Penzance would appear remote. Had the beach travel been from east to west, then there would have been less delay, owing to the much larger quantity of material that would have accumulated in its travel round the southern coast. Throughout a large portion of the foreshore Penzance has a natural advantage for maintaining a beach, owing to the circumstance that reefs of rocks, composed of elvan dykes and greenstone, extend for a considerable length parallel to the shore. These high ridges of durable rocks form natural breakwaters and groynes for the protection of the sea-wall and for accumulation of beach, especially as they run about at right angles to gales blowing into the bay from the south-east, the south, and the south-west; the heaviest seas here are those driven in by the south-east gales. In the most exposed position occurs the chasm formed by the cross-course, which acts as a channel for guiding the full force of the heaviest seas up against the Penzance sea-wall. The severe scour that takes place at this particular point has eroded the material in the chasm to a depth of ten feet below the level of the foreshore on either side. The difference in the cost of maintenance of the sea-walls where protected by the natural groynes of rock, and where subjected to the full force of the sea, has been great. The gap between the rocks has involved the expenditure of large sums, besides the lowering of the beach by the scour. This experience demonstrates that, as the ridges of rocks form natural groynes which run parallel to the coast-line, any artificial groynes placed for the protection of the coast should

[illegible] The [illegible] of the ocean bed was [illegible] which was generally [illegible]. It is now associated [illegible] Immediately in [illegible] with beds of greenstone, [illegible] The greenstone is a hard, [illegible] the result of metamorphic [illegible] Among the range of [illegible] The elvan or [illegible] remains [illegible] the latter has been [illegible] The latter is more affected by erosion than [illegible] Passing through all these [illegible] runs a [illegible] filled with [illegible] It forms an open channel of greater [illegible] and through it the full [illegible] against the sea-wall at Penzance.

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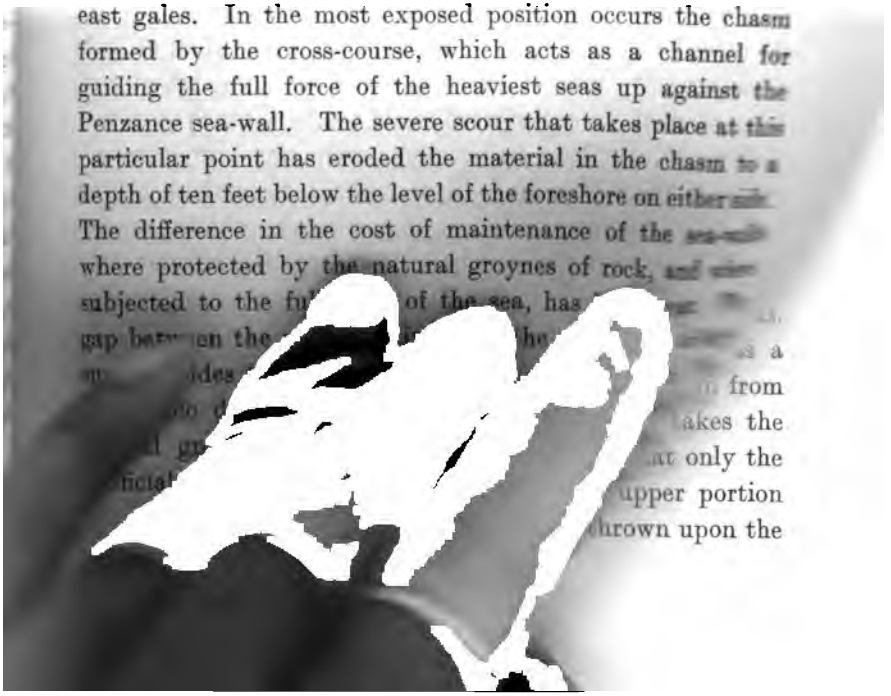

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also run more or less parallel to the coast-line. The advisability of continuing all such groynes down to low-water of spring tides, or to such a position as will afford a natural angle of repose to the shingle or sand accumulated on the beach, is sufficiently recognised by engineers.

Sufficient consideration, the author thinks, is not always given as to the best materials to be adopted in groynes, from an economic point of view. Bearing in mind the varying conditions of tides and other circumstances existing around the coast, together with the hazardous schemes of groyning that are frequently projected, many of which must unaccountably fail to answer the purpose intended, the author believes that much expenditure would be avoided if materials were adopted which would involve the lowest outlay for completing the groynes in such a way that they might be allowed to remain intact for a period reasonably likely to be sufficient for proving the plan a success or otherwise. Should the attempt be the means of building up a satisfactory beach, the groynes would become buried, and the materials with which they are constructed would be of little consequence. If, on the other hand, the plan proved a failure, it would be of little consequence to remove the structures, and, the initial cost being nominal, the experiment would not be so much regretted as it would have been had a more costly plan been adopted. An error frequently made is to restrict the extent of the groynes; it is practically as impossible to obtain success from groyning a limited and isolated area as from insufficiently groyning an extensive area. The plan of groynes now adopted for Penzance is at present in an experimental stage.

Sea-wall.—Turning to the work that was immediately essential as the result of the chasm already described, the cross-course in the bottom of the chasm, and likewise the killas on each side thereof, had become so extensively eroded that in the latter part of the winter of 1902–3 the sea-wall

was undermined and was practically collapsing. The first portion of the sea-wall which began to collapse was at the middle of the chasm, and the danger increased so rapidly, eastward and westward, that urgent steps had to be taken for preventing a total collapse. The face of the old wall consists of blocks of granite, each with an average exposed surface of 12 square feet. These are headers and stretchers, backed with huge stones and clay, into which the lighter face-wall is bonded by occasional deeper headers. The base of the wall has shown signs of weakness for some time, but the upper portion was in a state of good preservation, and had been strengthened by concrete. The condition had become serious owing to the time being so limited for carrying out any new work previous to the winter gales. The author accordingly designed a curtain wall or projecting base or "berm" wall to be built against the lower half of the old wall and properly bonded into it, so that, in conjunction with the upper half of the old wall, the whole should make one good, solid structure. The plan was accepted by the Council, and the Local Government Board granted a loan on the work, extending over the usual period now allowed for sea works—namely, twenty years.

Berm.—The construction of the "berm" shown in Fig. 1, is the more interesting because it exemplifies a method which the author considers to be of great assistance in rapid building during winter months, inasmuch as every short length of the face work is separately made secure, and the joints are bonded, both horizontally and vertically, as the work proceeds. By means of this projecting base, which can be used as a promenade in fine weather, the heavy rollers coming in from the sea are broken up in two stages. The base takes the weight of the attacking wave, and breaks it so that only the crest or broken water is thrown against the upper portion of the original wall. The quantity of water thrown upon the

promenade along the top of the wall is thus reduced to a minimum. At the same time, owing to the fact that the wave is broken in two stages, its return to the sea is retarded, and the former severe scouring of the beach is greatly reduced.

Foundations.—In so exposed a position, a strong, substantial construction was essential. The foundations for the berm, below those of the old wall, were excavated in a trench six feet wide, leaving sufficient width of undisturbed killas between the old wall and the trench for the safe support of the old wall. The trench was opened in sections, which were properly timbered with close runners; and each length was covered over for every tide with substantial iron plates, which were well weighted down with bags of sand and shingle. The foundation courses consisted of granite headers and stretchers, the former not less than 2 feet in depth from front to back, and the latter 1ft. 6in.; and no stone was used of greater height than the depth of its bed. These courses were set and jointed in mortar, consisting of a 1-measure of Portland cement to 1-measure of good, clean, sharp sand mixed with sea-water, and were pointed with neat cement as the work proceeded. The space between the face of the foundation and the side of the trench, after the runners were removed, was filled in with concrete of good quality, so that no weak spot should be left at the foot of the wall. The granite facing wall was backed with Portland cement concrete to the width of the excavation. The concrete consisted of cement, trass, gravel, and sharp sand, gauged 4 measures of gravel from $\frac{1}{2}$ inch down to $\frac{1}{16}$th inch with 1 of sharp beach sand, 1 of Portland cement, and $\frac{1}{9}$th of a measure of trass.

Superstructure.—On completion of the foundation, the construction of the superstructure was carried on in sections; and each length was finished and paved before proceeding with the next. From the diagram, Fig. 6, it will be observed that all the courses in the face of the wall are constructed

with joints broken both vertically and horizontally. The author's theory is that a wave, in attacking a wall at right angles to its direction of motion, as is here the case, exerts its force in a horizontal line throughout the length of the wall; and in the event of unbroken horizontal joints the strain must, in consequence, be unequally distributed—that is, must be greater along that particular horizontal line than along those above or below it. Hence, the safety of the wall must depend much on the weight of the structure and on the soundness of the jointing materials. In the present wall long lengths of horizontal joints are avoided, in order to distribute the strain throughout the depth of the structure, and so to render it impossible for any one single course to be carried away without either breaking through solid granite blocks or separating the courses below.

The courses are laid with headers and stretchers, as shown on the profile Fig. 1, with ashlar granite face, battered 3 inches per foot vertical. The courses are bedded and jointed in mortar, consisting of equal measures of Portland cement and clean, sharp sand, and $\frac{1}{9}$th of a measure of trass; and the work is pointed in neat cement. Above the foundation the facing ashlar is reduced 6 inches in thickness from front to back, the stretchers are 12 inches deep, and the headers 1ft. 6 in. Every vertical bonding stone or "jumper" is of additional depth, in order to afford strength to the horizontal joints and extra tie into the concrete. For a distance of 2 feet from the back of the ashlar facing, the work is packed solid with specially gauged concrete, consisting of 2 parts sharp quarry stone siftings, ranging from $\frac{1}{2}$ inch down to the size of a pin's head, and 1 part small beach gravel about the size of peas, and 1 part sharp beach sand; to this was added 1 measure of Portland cement, and $\frac{1}{9}$th of a measure of trass. The same kind of material is placed against the face of the old wall for 1 foot in thickness.

The remaining space between the two walls is made solid with concrete, gauged 4 measures of beach gravel and sand, mixed in proper proportions, and 1 of Portland cement. In this "fig" stones were allowed to be bedded 6 inches apart; they were required to be rough granite spalls of irregular shape; no round cobbles or other smooth stones were admitted.

Coping.—The coping course, being exposed to considerable danger, received careful consideration. The facing course immediately below the coping is made 6 inches deeper than the rest of the headers and stretchers, and the jumpers breaking joint vertically are proportionately large. This course was solidly packed with mortar and concrete. At intervals of every 3 ft. a vertical 1¼ in. iron bolt, with head at top and nut and washer at bottom, was bedded 12 inches in the concrete, behind the facing stones. As illustrated in Figs. 2, 3, 4 and 5, the coping was designed as follows:—Each coper was made to break joint with the face work, and also with the paving on the surface, as shown in diagram 4 and 5. The back of the coper was tooled to the depth of the thickness of the paving stones, and its remaining depth was rough splayed at back in the form of a foot, to be embedded in the concrete backing, so that the stone could not be removed without tearing away the concrete and lifting the paving at the back (see Fig. 2). The ends of each stone are provided with vertical joggles. These consist of a dove-tail chase cut vertically in corresponding positions through the full thickness of each stone, 3 inches deep, 2 inches wide at the gap, and splayed out ½ inch on each side of the gap, as shown in Figs. 2 and 3. The coping stones were bedded round their edges in mortar; the joints were then caulked with sack-cloth; and the dove-tail joggle, which contains in one end 1½ or 2 feet length of the vertical 1¼ inch bolt previously embedded into the concrete (Figs. 2 and 3) was grouted with neat cement grout, and worked with a

"sword" until the grout flowed under and around the stone; and all joints, including the joggle, were filled solid with cement, as illustrated in Fig. 4.

Paving.—The paving between the old wall and the coping stones is done with granite flags, having shoddy picked joints. The minimum thickness of the flags is 6 inches, and their surface 9 square feet. The method adopted for bedding them was of importance; as they are of no great thickness, it was essential that they should be bedded solid. They were, therefore, laid on an edging of cement about 6 inches in width, which continued all round the margin of the flag with the exception of about a foot; and a space of about an inch was left between the underside of the flag and the surface of the ordinary concrete. Each slab so "set up" was grouted with cement grout through, the opening of about a foot already referred to remaining between this and the stone previously laid. The slab was always benched about ½ inch too high until this process was completed, and was then well pummelled down to its proper level. Any surplus grouting was thereby driven through the joints, and in this way effectually made the joints between the abutting flags, so that there was perfect cohesion between the concrete and grout under and all round the granite slab, rendering it impossible for any hollow space to remain under any slab.

Bonding.—In executing this berm great care was exercised to bond the new work effectually into the old wall, for the purpose of adding stability to the old rather than of obtaining support for the new. The method adopted is shown in Fig. 1. At intervals along the old wall, single stones were removed at different levels, so that the wall should not be weakened by cutting them all out in the same horizontal course. Into each opening so made a large bonding stone was then inserted and securely fixed into the wall with cement while the projecting portion was incorporated in the concrete backing of

the new work. Iron bars were also driven into the joints of the old wall at frequent intervals and at various angles. In places where considered advisable, strands of hoop iron were embedded in the concrete, and their ends made fast round vertical iron bars, also embedded therein. The face of the old wall was cleaned before any of the special concrete was applied to it; the joints were raked out as far in as they had become eroded, and the whole surface was brushed over with cement wash.

The berm now completed forms practically a monolithic structure. The face work provides the essential protection to the concrete against the erosive action of the beach stones.

The coping, which receives the full weight of the storm, and is frequently the weak part of a wall, is in this instance rendered extra secure; and the concrete backing is of the most durable and solid description. A wall so constructed is of great strength, and the author is of opinion that this mode of construction is to be preferred for strength to the building of sea-walls with huge blocks of stone. With the present facing ashlar of small size there is little trouble in completely filling the joints, and the stones are quickly and easily handled.

Moreover, when larger blocks are used, they themselves constitute the strength of the wall, and reliance must be placed on their being perfectly cemented together. But, on the author's plan, not only are the facing stones firmly secured, but the concrete behind them forms the main strength of the wall, and is free from both horizontal and vertical joints. The relative cost of the two methods of construction is shown by the annexed estimates, giving—firstly, the cost of the present work; and secondly, that of a similar design if carried out with heavy blocks.

Cost of the Construction actually Adopted.

410	c. yds.	of Ashlar masonry, at £1 15s. 0d. ..	£717	10	0
323	s. yds.	of Granite paving, at £1 5s. ..	403	15	0
1,200	c. yds.	of Excavating, at 4s.	240	0	0
15	,,	of Steps, at £3	45	0	0
1,321	,,	of Concrete, at 16s. 6d.	1,089	16	6
30	,,	of Granite tie stones, at £1 10s. ..	45	0	0
Hacking out present joints, and cutting out blocks of masonry for uniting new and old work ..			43	0	0
Timbering trenches			120	0	0
Crane and pumping charges			165	0	0
Clerk of Works, 24 weeks at £2			48	0	0
Contingencies			282	18	6
			£3,200	0	0

The Cost of Construction with Heavier Blocks.

1,000	c. yds.	of Ashlar masonry in heavy blocks, in cement mortar, at £1 15s. ..	£1,720	0	0
323	s. yds.	of Granite paving, at £1 5s. ..	403	15	0
1,200	c. yds.	of Excavating, at 4s.	240	0	0
15	,,	of Steps, at £3	45	0	0
731	,,	of Concrete, at 16s.	584	16	0
30	,,	of Granite tie stones, at £1 10s. ..	45	0	0
Hacking out present joints, and cutting out a course of masonry for uniting the new and old work ..			43	0	0
Timbering trenches			20	0	0
Cranes and pumping charges			350	0	0
Clerk of Works, 24 weeks at £2			48	0	0
Contingencies			300	0	0
			£3,799	11	0

Dynamometers.—During the past four years the author has been making experiments with a view to arriving at some

data, of a reliable and general character, respecting the force of the sea during storms. Four dynamometers have been constructed for this purpose, which were fixed in exposed positions at Penzance and elsewhere, but up to the present only one reliable record has been obtained at Penzance, which is as follows:—21st November, 1902, Dynamometer No. 1 Compression of spring, 6 inches. Resistance, 110 lbs. per inch of compression. Area of striking plate, 48 sq. ins. Force recorded, $6 \times 110 \times 144 \div 48 = 1{,}980$ lbs. per sq. foot. Depth of water, 12½ feet in chasm between rocks. Dynamometer, 5½ feet above beach at chasm. Wind, south. Sea, rough, owing to Atlantic gale. Anemometer reading, an hour before high tide, 4,200 feet per min., or 49 miles an hour.

The storms during the past winter (1903–4) would have offered much scope for such tests, but the progress of the works for the new sea-wall prevented advantage being taken of the most favourable positions for fixing the dynamometer. The instrument, two of which are illustrated in Fig. 7, is of simple construction, consisting of a strong cast-iron box, about 7½ inches cube. On each side of its open front, facing the sea, is an ear or lug for bolting it to the face of the sea-wall, into which it is let horizontal and flush. The open front is loosely fitted with a square striking or pressure plate, supported behind by a helical spring. A central steel spindle or bolt sliding freely through the back of the box, and having a head on its rear end, passes through the spring, and on its front squared end the pressure plate is secured by a nut outside. A stout leather collar or washer is slid upon the spindle, having its edge pinked round the hole, so as to grip the spindle tight in any position; before bolting the pressure plate on, the washer is pushed back close up against the inner face of the back of the box. The blow, or the sea striking upon the face of the pressure plate, drives it inwards, pushing the spindle back through the leather collar and through the rear

of the box, and thereby sliding the collar forwards along the spindle. In the recoil of the spring the collar is carried forwards by the spindle, while the head on the rear end of the spindle prevents the pressure plate from being shot out of the box. When the tide has ebbed low enough the pressure plate is unbolted and taken off, and the position of the washer upon the spindle records the travel due to the concussion of the waves, thus registering only the maximum blow struck by the sea during the storm. The hole in the wall in which the box is fixed is recessed far enough behind to allow of the spindle making its full backward stroke free of obstruction. The spring is tested beforehand to ascertain the extent of compression under successive cwts. of load upon the pressure plate; it is held horizontal and central in the box by four snugs at each end, on the inside of the pressure plate and of the back of the box.

It is important in these instruments that sufficient space should be left between the striking plate and the box for the purpose of drainage, thereby preventing the "dash pot" action.

Mr. F. J. Dick, C.E., of the Board of Works, Dublin, who has taken interest in the author's observations with the dynamometer, has suggested that further tests in accordance with the force diagram shown in Fig. 8 would be of considerable interest, as by such tests the true nature of lines AB and CB would be arrived at, which appear not to have been definitely ascertained by any previous experiments. The author at this time had two additional dynamometers made with the object of obtaining the desired forces, but the instruments were removed, owing to the progress of the new sea-wall, before any records were obtained, but he hopes to follow up his observations at a future opportunity.

The curtain wall or "berm" at Penzance was designed to be of such strength that, when once the coping stones were

in position and the work had been allowed to set for a week, or even less, the whole or any portion should be able to resist a greater shock than that exerted by the sea. In so exposed a position, and with short intervals of the work being left uncovered by the tide, it was necessary to provide for the maximum impact of the sea occurring at almost any moment. As the work was being carried out during the winter months this provision was most essential.

Cohesive Strength of Cement and Concrete.

Regular tests of the materials used in the concrete have been carried out by the author, many of which are here recorded. They were made in order to maintain the standards required by the specification, which gave a safe factor of strength from the time that the coping and paving were set. The following were the standards upon which the work was designed:—Cohesive resistance of cement and granite, after 7 days' immersion in water, 58 lbs. per sq. inch. Tensile strength of cement, after 7 days' immersion in water, 400 lbs. per sq. inch. Cohesive strength of cement mortar, made as specified, after 7 days' immersion, 40 lbs. per sq. inch. Cohesive strength of concrete, made as specified, for backing in conjunction with granite, after 7 days' immersion, 25 lbs. per sq. inch. Tensile strength of cement mortar, after 7 days' immersion, 60 lbs. per sq. inch. Tensile strength of ordinary 4 to 1 concrete backing, 35 lbs. per sq. inch. From these figures it was calculated that the coping stones would be equal to resisting the following stresses:—

Dove-tail joggle, 60 sq. in. ..	..	16,800 lbs.
Granite foot behind into concrete 36″ × 5″ projecting ..	..	12,600 ,,
Adhesive surface of stone ..	..	115,200 ,,
Holding bolts, each ..	..	1,500 ,,
Total,	..	146,100 lbs.

This is equal to $\frac{146,100}{6}$, or 24,350 lbs. per sq. foot, for the smaller coping stones of 3 × 2 feet area on top.

Trass.—While considering the details of the new sea-wall at Penzance, the material known as trass was brought to the author's notice, and he took steps to arrive at its value for such works.

The following tests, made by him during the time the works were in progress, he thinks will be found useful to engineers engaged in any description of structural work where cements and concretes are employed.

Although trass is extensively used in many places abroad, its origin and value are little known at present in this country. Ample evidence is afforded that in the days of the Romans the stone known as tufa was quarried and used for mortar. There are two opinions as to the origin of tufa or tuffstone. One is that it is the ashes of a volcano, which by the action of water and pressure, have become conglomerated into one mass. The other opinion, which from obvious proofs, is the more generally accepted by geologists, is that, like lava, it is a mud of volcanic origin which flowed down and settled in the valleys. Only in the valleys is it found in quantities; and that it was not at any high temperature during the period of deposit is shown by the fact that charred pieces of trees and shrubs are found embedded in it, which would certainly have been burnt up had the stone been the result of volcano ashes. That the tufa was cooled by water is also well attested by geologists; and, no doubt, it was partly from this cause that it gained its property of setting under water as a hydraulic cement.

Trass is ground tufa or tuffstone. It is found in abundance in the Eifel District in the Rhenish Province of West Prussia, and has for years been employed as an addition to lime, both

quantity of powdered trass into a glass of water, and observing how quickly it sinks, and what length of time it takes for the water to become clear, and what is the quantity of the pumice that floats on the surface. This test is of little value with finely milled trass, but it can be employed with good results when the grinding is done on the works, by taking a sample from the mill before it becomes ground fine enough for use.

The Dutch specification of 1895 includes the following tests for trass :—A litre of hard rammed trass must weigh at least 1.15 killogram—that is, 1 pint must weigh 1.44 lb., or 1 bushel 92 lbs., or 1 cubic foot 72 lbs. The needle test requires that a mixture of two volumes of fat lime powdered and properly slacked with one volume of trass, mixed to the condition of fresh paint, should be able, after being submerged under water for 24 to 48 hours, to stand the Vicat needle loaded with 300 grammes, or 10.58 ounces. Tensile tests are made by mixing 2 parts of lime, by weight, with 2 of trass and 3 of normal sand and 0.90 to 0.95 of water. Normal sand is that which passes through a sieve of 60 meshes per sq. cm., or 387 per sq. inch, and remains on a sieve of 120 meshes per sq. cm., or 774 per sq. inch. After the mixture has been exposed to damp air for one day and immersed in water for 13 days it should withstand a tensile strain of 8 kg. per sq. cm. (114 lbs. per sq. inch), and a compression strain of 40 kg. per sq. cm. (570 lbs. per sq. inch). After 28 days' immersion these figures must amount to at least 12 and 60 kg. per sq. cm. (170 and 850 lbs. per sq. inch) respectively. The chief test for the good quality of trass is that for determining the hygroscopic water and the hydrate contained in the material. This twofold result can be ascertained by the Dutch test of 1895, for which the trass is first dried, and then a sample of 20 grammes or 300 grains, or say $\frac{3}{4}$ ounce, is pulverised till all of it passes through a sieve of 5,000 meshes per sq. cm., or 32,277 per sq. inch, or 180 per lineal inch. By now heating

it the hygroscopic water is driven off, and the quantity so expelled is determined by the loss of weight.

Good trass should lose about 7 per cent. of its weight drying, and any which so loses between 5½ and 7½ per cent. can be used, provided it fulfils the tensile tests. According to the Royal Commission of Germany, 10 grammes, or 150 grains, or ⅜ ounce, of the trass pulverised and sifted as above, should be put into a weighing glass of at least 4 cm., or 1½ inch, diameter, having a close-ground, air-tight stopper. The glass is placed in a drying oven, with the stopper laid sideways in the mouth, so as to be loose enough for allowing the free escape of the moisture driven off. The oven has a jacket, through which water and air are kept circulating. The temperature is raised to 98° Celsius, or 208° F., and is kept constant thereat for 3 hours. Then the glass is tightly stoppered, taken out, and placed directly under a bell-jar to cool. The decrease in weight of the trass is the amount of hygroscopic water dried off.

The water chemically combined as hydrate is determined by heating the remaining 10 grs. of the ground and sifted trass in a platinum or porcelain crucible either for 30 minutes over a gas flame, or in a Hempel oven for at least 40 minutes. Care must be taken that the heating is not carried out too quickly at first, on account of the water and air contained in the trass, but so slowly that only at the end of 5 to 10 minutes does it become red hot. When it is heated too quickly the air and water it contains burst out with such force as to carry off small particles of the trass with them, and thus falsify the test. At the end of the heating the crucible is taken with a pair of hot tongs and placed under a bell-jar to cool. After it is thoroughly well cooled the decrease in weight is ascertained by weighing, and is calculated in percentage of the dried trass—that is, the trass from which its hygroscopic water has been dried out.

A theory was started in 1896 by Dr. Michäelis, of Berlin, that by the addition of trass within certain limits Portland cement and lime mortars would be improved and rendered more fit to withstand the action of the sea-water. Subsequently, both in Germany and in Holland, the question arose, whether trass acted only as a fine sand, or whether its action was chemical. Dr. Michäelis' theory was that the hydraulic binding agents, rich in lime, are the least capable of resisting the action of sea-water; and that free lime—that is, lime which has become free—is the chief cause of the collapse of cement and mortar in sea-water; and that by the addition of trass the free lime is taken into chemical combination by the silica contained in the trass, thus adding to the "real cement" in the mortar. This theory has now been established by tests made on the Island of Sylt by the Royal Commission, who concluded that within certain limits the addition of trass is beneficial to Portland cement.

Analysis of Trass.—The chief ingredient in trass is silica, which, as seen from the following analysis by Mr. D. B. Butler, the President of the Society of Engineers, London, constitutes more than half the weight of the material:—

	Soluble per cent.		Insoluble per cent.		Total per cent.
Water and Carbonic Acid ..	9.83		—		9.83
Silica	33.38	+	20.78	=	54.16
Alumina	14.88	+	6.55	=	21.43
Oxide of Iron	2.53	+	0.50	=	3.03
Lime	1.82	+	1.05	=	2.87
Magnesia	1.16	+	0.60	=	1.76
Soda	1.20		—		1.20
Potash	3.70		—		3.70
Alkalies, &c.	—		0.96		0.96
Total,	68.50	+	30.44	=	98.94

Its fineness was ascertained by sifting it through three successively coarser meshes—namely, 100 holes per lineal inch × 100 = 10,000 per square inch; 76 × 76 = 5,776; and 50 × 50 = 2,500. The residues left on these sieves were, respectively, 27 and 19 and 10 per cent.

Lengthy experiments carried out by the author convinced him of the advantage derived from the addition of trass to mortar in contact with sea-water, and led him to employ it in the cement concrete, and mortar for the principal portions of the Penzance new sea-wall. He first tested cement and trass mixed together in the following proportions, by measure, and immersed in water for the number of days stated, after which their tensile strength was ascertained in lbs. per square inch.

Series 1.—When mixed with sea-water and immersed in sea-water for the number of days stated, the strength was—

Lighthouse brand cement, neat,	20 days	320 lbs.,	72 days	420 lbs.
1 trass and 9 cement,	,,	350 lbs.,	,,	500 lbs.
1 trass and 1 cement,	,,	290 lbs.,	,,	390 lbs.

Series 2.—When mixed with fresh water and immersed in fresh water, the strength became less—

Lighthouse brand cement, neat,	20 days	310 lbs.,	72 days	400 lbs.
1 trass and 9 cement,	,,	290 lbs.,	,,	320 lbs.
1 trass and 1 cement,	,,	180 lbs.,	,,	270 lbs.

Series 3.—Gauged with sea-water and immersed in sea-water—

Hilton and Anderson's cement, neat,	70 days	585 lbs.		
1 trass and 6 cement,	,,	520 lbs.		

From these tests the author concluded that the advantage to be gained by the addition of trass was not so great when the mixture was made with neat cement as it would be when the trass was added to cement-mortar or to concrete. Several mortar briquettes were therefore made in the following proportions:—16 oz. selected beach sand, 12 oz. Portland

cement, 4 oz. trass. One lot was gauged and immersed in sea-water, in which also the sand was washed; and for another lot fresh water was used throughout.

Series 4.—The tensile strength in lbs. per square inch was—

21 days,	sea-water	182 lbs.,	fresh water	160 lbs.
6 months,	,,	410 lbs.,	,,	382 lbs.
9 months,	,,	503 lbs.,	,,	414 lbs.

Series 5.—Briquettes made at the same date with similar sand and cement, 16 oz. of each, and no trass—

21 days,	sea-water	193 lbs.,	fresh water	203 lbs.
6 months,	,,	356 lbs.,	,,	442 lbs.
9 months,	,,	428 lbs.,	,,	*120 lbs.

Series 6.—Mixture of 36 oz. selected beach sand, 4 oz. Porthcurnow shell sand, finely calcined, 16 oz. cement, 4 oz. trass—

14 days,	sea-water	75 lbs.;	fresh water	82 lbs.
21 days,	,,	116 lbs.;	,,	98 lbs.
6 months.	,,	320 lbs.; 352 lbs.;	,,	265 lbs. 248 lbs.
	Average,	336 lbs.;	Average,	256½ lbs.
9 months,	sea-water	438 lbs.; 400 lbs.; 460 lbs.;	fresh water	310 lbs. 352 lbs. —
	Average,	433 lbs.	Average,	331 lbs.

Series 7.—Same aggregate, except with 20 oz. cement and no trass—

14 days,	sea-water	132 lbs.;	fresh water	116 lbs.
28 days,	,,	196 lbs.;	,,	232 lbs.
3 months,	,,	283 lbs.;	,,	damaged
6 months,	,,	352 lbs.; 329 lbs.;	,,	85 lbs. 382 lbs.
	Average,	340½ lbs.	Average,	383½ lbs.

* This briquette was faulty, probably as the result of injury in removing it from the mould.

9 months, sea-water	392 lbs.; 365 lbs.; 405 lbs.;	fresh water	476 lbs. 432 lbs. 443 lbs.
Average,	387 lbs.;	Average,	450 lbs.

Series 8.—Mixture of 20 oz. coarse, gritty beach sand, 4 oz. fine wind-blown sand, 5 oz. cement, 1 oz. trass—

28 days,	sea-water	126 lbs.;	fresh water	*83 lbs.
3 months,	,,	345 lbs.;	,,	253 lbs.
6 months,	,,	318 lbs.;	,,	285 lbs.
9 months,	,,	372 lbs.;	,,	306 lbs.

Series 9.—Same aggregate, except with 6 oz. cement and no trass—

28 days,	sea water	145 lbs.;	fresh water	160 lbs.
6 months,	,,	358 lbs.;	,,	406 lbs.

Series 8 and 9 prove the value of the admixture of the 4 oz. of fine sand over the use of coarse sand only, and Series 6 and 7 show that the addition of finely calcined shell does not give so good a result as that of fine sand.

Series 10.—Mixture of 30 oz. coarse, gritty beach sand, 6 oz. fine wind-blown sand, 5 oz. cement, 1 oz. trass—

3 months,	sea-water	120 lbs.;	fresh water	142 lbs.
6 months,	,,	203½ lbs.;	,,	204 lbs.
10 months,	,,	286 lbs.;	,,	231 lbs.

Series 11.—Same aggregate, except with 6 oz. cement and no trass—

3 months,	sea-water	109 lbs.;	fresh water	135 lbs.
6 months,	,,	188 lbs.;	,,	195 lbs.
10 months,	,,	220 lbs.; 255 lbs.;	,,	268 lbs.
Average,		237½ lbs.		

* Test piece slightly damaged in section in removing it from the mould.

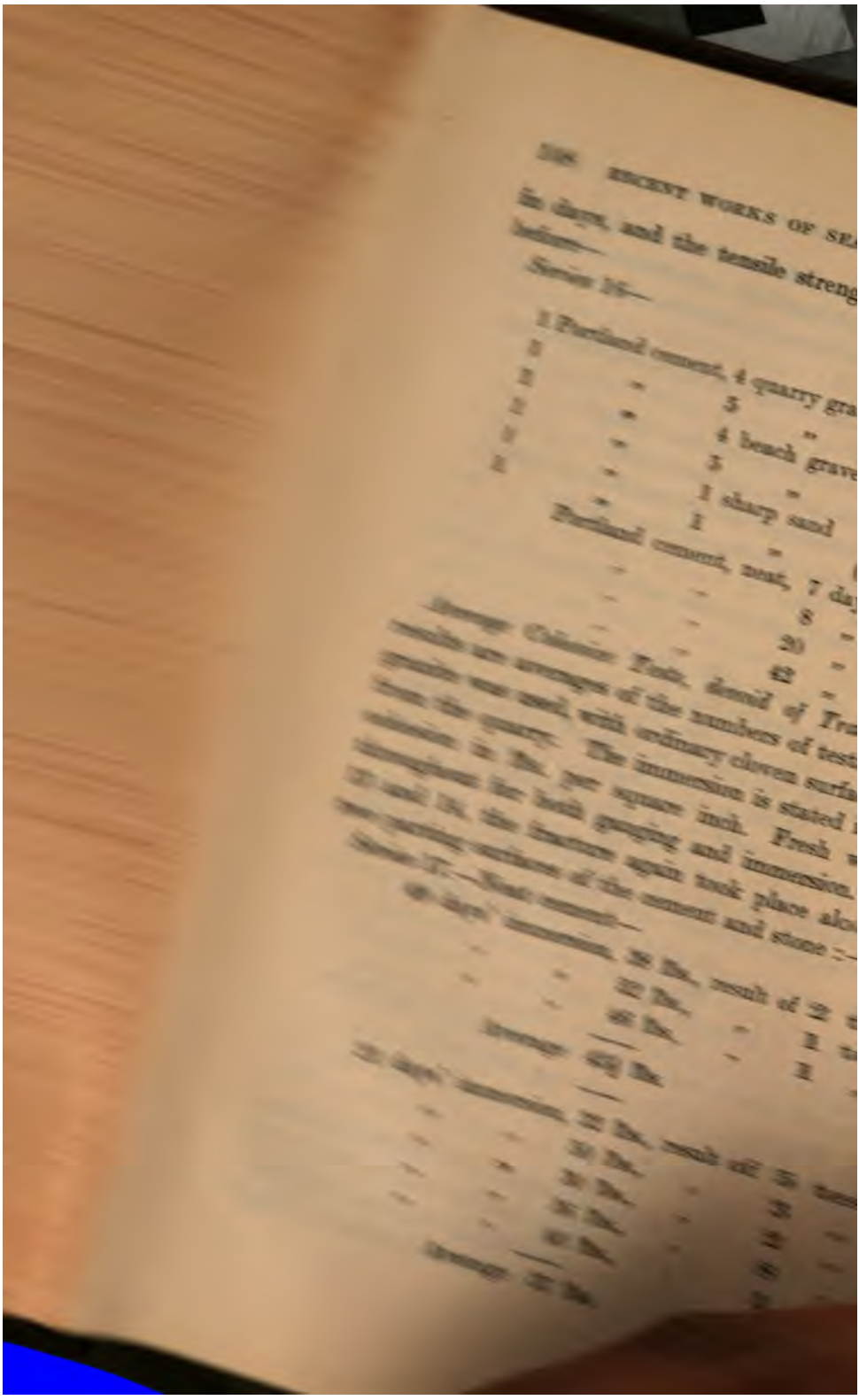
Series 10 and 11 are important as showing that, with 1 cement to 6 sand, gauged by weight in mortar or concrete, the substitution of trass for one-sixth of the weight of cement gives as good a result in sea water, if not a better, than when the full weight of cement is used alone, without any trass. In sea works, therefore, the author considers that, in all mortar or concrete gaugings from 1 and 1 up to 1 cement and 6 sand, trass may, with beneficial result, be substituted for cement to the extent of one-sixth of the weight of the cement which would otherwise be used without trass. As trass costs only half as much as the same weight of cement, its adoption would reduce by 50 per cent. the outlay on the weight substituted for cement, or by one-twelfth the total cost of cement.

Series 12.—The following are the results of tensile tests made by Messrs. Henry Faija & Co., in order to determine the effect of admixture of trass upon briquettes of Portland cement mortar, gauged in varying proportions, by weight, and after twelve months' immersion. The admixture of trass was in addition to the full quantity of cement, and the same water—sea or fresh—was used both for gauging and for immersion. The tensile strength is in lbs. per square inch, as before :—

2 sand,	1	cement,		sea-water	452 lbs. ;	fresh water	586 lbs.
3 ,,	1	,,		,,	413 lbs. ;	,,	444 lbs.
4 ,,	1	,,		,,	242 lbs. ;	,,	340 lbs.
4 ,,	1	,,	1 trass,	,,	701 lbs. ;	,,	606 lbs.
5 ,,	1	,,		,,	231 lbs. ;	,,	291 lbs.
5 ,,	1	,,	1 trass	,,	704 lbs. ;	,,	552 lbs.

Here it is seen that the mortar devoid of trass was stronger with fresh water than with sea ; and that the admixture of trass in equal weight with the cement not only reversed this relation, but also increased the strength of the mortar nearly twofold with fresh water, and about threefold with sea-water.

Testing Cohesive Strength.—In all descriptions of masonry



14 days' immersion, 35 lbs., result of 3 tests.
,, ,, 29 lbs., ,, 2 ,,

Average 33 lbs.

7 days' immersion, 18 lbs., result of 3 tests.
,, ,, 30 lbs., ,, 1 ,,
,, ,, 22 lbs., ,, 1 ,,

Average 21 lbs.

6 days' immersion, 34 lbs., result of 1 test.
,, ,, 25 lbs., ,, 1 ,,
,, ,, 19½ lbs., ,, 1 ,,

Average 26 lbs.

Series 18.—Mortar of 1 measure cement and 1 sand—
49 days' immersion, 32 lbs., result of 1 test.
,, ,, ,, 42 lbs., ,, 1 ,,

Average 37 lbs.

21 days' immersion, 17 lbs., result of 1 test.
,, ,, 40 lbs., ,, 3 tests.
,, ,, 20 lbs., ,, 2 ,,
,, ,, 35 lbs., ,, 5 ,,
,, ,, 27 lbs., ,, 1 test.

Average 32 lbs.

14 days' immersion, 25 lbs., result of 1 test.
,, ,, 27 lbs., ,, 3 tests.

Average 26½ lbs.

7 days' immersion,	18 lbs.,	result of	1 test.
,, ,,	34 lbs.,	,,	1 ,,
,, ,,	24 lbs.,	,,	2 tests.
Average	25 lbs.		

Series 19.—Concrete of 1 measure cement, 1½ sand, and 3 beach gravel—

14 days' immersion	15 lbs.,	result of	1 test.
,, ,,	26 lbs.,	,,	1 ,,
Average	20½ lbs.		

7 days' immersion	12 lbs.,	result of	2 tests.
,, ,,	24 lbs.,	,,	3 ,,
Average	19 lbs.		

6 days' immersion,	18 lbs.,	result of	1 test.
,, ,,	16 lbs.,	,,	1 ,,
,, ,,	9 lbs.,	,,	1 ,,
Average	14 lbs.		

In conclusion, the author desires to record his indebtedness to the Mayor and Corporation of Penzance—particularly the Chairman, Alderman James Caldwell, J.P., and Members of the Highway Committee; the Chairman, Alderman W. H. Julyan, J.P., and Members of the Quay Committee, under whose authority all works of sea defence directly come—for advantages and assistance in connection with the subject dealt with in this paper. He would also thank Mr. W. J. Johnston, of Westminster, for his kindness in supplying information and facilities regarding the manufacture of trass.

The author is also indebted to Messrs. Robert Johnston and Co., the agents for trass in England, for the appended calculations of outturn of mortars and concretes, with cost.

APPENDIX.

Mixture	Weight per cub. yd. in lbs.	1 cub. yard occupies in ready Mortar	Total mass occupies in ready Mortar	Price per cub. yd.	Total Price
c. yds.		c. yds.		s. d.	s. d.
½ Trass	1685	0.483	.241	19 3	9 7½
½ Cement	2527	0.479	.239	33 10	16 11
2 Sand	2527	0.600	1.200	4 0	8 0
5 Gravel (broken stone)	2527	0.600	3.000	4 0	20 0
⅔ Water	1685	1.000	.600	—	—

8.6 cub. yds. Mixture give .. .. 5.280 cub. yds. s. d.

of ready Mortar and costs 54 6½

Therefore 1 cub. yd. of ready Mortar costs 10 3¾

Mortar dense.

Mixture	Weight per cub. yd. in lbs.	1 cub. yard occupies in ready Mortar	Total mass occupies in ready Mortar	Price per cub. yd.	Total Price
c. yds.		c. yds.		s. d.	s. d.
½ Trass	1685	0.483	.241	19 3	9 7½
1 Cement	2527	0.479	.479	33 10	33 10
3 Sand	2527	0.600	1.000	4 0	12 0
9 Gravel (broken stone)	2527	0.600	5.400	4 0	36 0
1 Water	1685	1.000	1.000	—	—

14.5 cub. yds. Mixture give .. .. 8.920 cub. yds. s. d.

of ready Mortar and costs 91 5½

Therefore 1 cub. yd. of ready Mortar costs 10 8½

Mortar dense.

7 days' immersion...

Average

Series II.—Concrete

¾ inch gravel—

14 days' imm...

Av...

7 days' ...

9 days'

	Mixture	Weight per cub. yd. in lbs.	1 cub. yard occupies in ready Mortar	Total mass occupies in ready Mortar	Price per cub. yd.	Total Price
			c. yds.		s. d.	s. d.
	...ent	2527	0.479	.479	33 10	33 10
	...l	2527	0.600	1·200	4 0	8 0
	...vel (broken stone)	2527	0.600	3.000	4 0	20 0
	...ter	1685	1.000	.600	—	—

...ub. yds. Mixture give .. .. 5.279 cub. yds. s. d.

of ready Mortar and costs 61 10

Therefore 1 cub. yd. of ready Mortar costs 11 9

Mortar dense.

lbs.	Mixture	Weight per cub. yd. in lbs.	1 cub. yard occupies in ready Mortar	Total mass occupies in ready Mortar	Price per cub. yd.	Total Price
			c. yds.		s. d.	s. d.
1	Cement	2527	0.479	.479	33 10	33 10
2	Sand	2527	0.600	1.200	4 0	8 0
6	Gravel (broken stone)	2527	0.600	3.600	4 0	24 0
½	Water	1685	1.000	.600	—	—

...ub. yds. Mixture give .. 5.879 cub. yds. s. d.

of ready Mortar and costs 65 10

Therefore 1 cub. yd. of ready Mortar costs 11 2½

Mortar dense.

Mixture		Weight per cub. yd. in lbs.	1 cub. yard occupies in ready Mortar	Total mass occupies in ready Mortar	Price per cub. yd.	Total Price
c. yds.			c. yds.		s. d.	s. d.
1	Cement	2527	0.479	.479	33 10	33 10
2½	Sand	2527	0.600	1.500	4 0	10 0
7	Gravel (broken stone)	2527	0.600	4.200	4 0	28 0
.7	Water	1685	1.000	.700	—	—

11.2 Mixture give .. .. 6.879 cub. yds. s. d.
of ready Mortar and costs 71 10

Therefore 1 cub. yd. of ready Mortar costs 10 5½

Mortar dense.

Mixture		Weight per cub. yd. in lbs.	1 cub. yard occupies in ready Mortar	Total mass occupies in ready Mortar	Price per cub. yd.	Total Price
c. yds.			c. yds.		s. d.	s. d.
1	Cement	2527	0.479	479	33 10	33 10
4	Sand	2527	0.600	2.400	4 0	16 0
10	Gravel (broken stone)	2527	0.600	6.000	4 0	40 0
1.0	Water	1685	1.000	1.000	—	—

16 cub. yds. Mixture give .. .. 9.879 cub. yds. s. d.
of ready Mortar and costs 89 10

Therefore 1 cub. yd. of ready Mortar costs 9 2

Mortar non-dense.

THE PRESIDENT (Mr. Cochrane) said they were greatly indebted to Mr. Latham for coming so far to read this paper, which had involved such an amount of work. It was only those who had undertaken such tasks that could form a correct idea of the time and study, in addition to practical experience, that was necessary to devote to the production of such a paper.

It was valuable because it was a description of work actually done, and it gave details of the methods adopted in execution.

The locality in which this work was done—Penzance—is a most interesting one, and is one of the most beautiful parts of a very interesting county—Cornwall—with Mounts Bay on the east, and that paradise of artists, Newlyn, on the west. The coast was exposed to storms as severe as anything they experienced in the south-west of Ireland. The engineer who sets to work to resist the action of the sea and prevailing S.W. winds here must have all his wits about him. It is quite evident Mr. Latham has been able to overcome this difficulty, and the results he had given them of his experiments were most interesting, and will be valuable for reference when recorded in their "Transactions."

With reference to the "tufa," its application was new in this country, and they had not much experience of it. Any geological deposits in this country were in small quantities, and of a porous, light quality. They would want to grind a large quantity to get much result.

Deposits of calcareous tufa of chemical origin are rare in this country, and the tufa from volcanic ash is rarer still—the latter formed from the lava rocks trachyte and basalt, though found in fragments varying from large blocks down to impalpable power, have not been made

use of for concrete work. Therefore, if they were to make use of tufa it would have to be imported.

He was sure they would all join with him in according a cordial vote of thanks to the author for his paper.

MR. M. PURCELL said he was very much interested in the paper. The only point that occurred to him was with reference to the dynamometer and the waves breaking against the sea-wall. He thought the records of these dynamometers were not all that they required. He thought in these experiments they had not taken into consideration the question of the "follow-on" after the blow. These dynamometers recorded the force of the impact of the sea, but not the weight of the sea coming behind and the actual push of this body. It might be the impact that hit the hardest, but it was his experience that it was the "follow-on" which disintegrated. He would like to hear the author's views on this subject.

MR. W. KERNAGHAN said a somewhat similar work to that which founded the subject of Mr. Latham's paper has been constructed on the coast at Barnageragh, midway between Skerries and Balbriggan, in the Co. Dublin.

The works, which are nearly completed, were carried out by Mr. Collen, County Surveyor, for the Dublin County Council, and were in his (Mr. Kernaghan's) immediate charge.

The object was to protect the public road, which was 70 feet above the beach. The old pitching had been washed away, and landslips occurred in the banks from springs and layers of quicksand.

It was found necessary to carefully sub-drain all the banks and protect the toe by curtain walls faced with ashlar—the ashlar facing being necessary to prevent the cutting action of the shingle on the concrete. See Section No. 1 and No. 2.

The angles in the pitched slopes and the berms tend to break the force of the waves by altering the direction of the impact.

The recessed portion between the north and south walls serves to collect and retain the shingle and partly arrest its travel.

The curtain walls were found necessary owing to the frequent lowerings of the beach by the travel of the shingle.

Sometimes the shingle is 4 feet below and sometimes 2 feet above high-water mark.

Mr. Latham, in reply, said, before replying to any of the questions that had been put, he would like to state how much he had looked forward to his visit to Ireland. He had been engaged in his spare time for nearly two years in getting together the material for the paper he had now the honour of reading before the engineers of Ireland.

He might say that he greatly appreciated the beautiful City of Dublin, with its splendid streets, magnificent buildings, and beautiful parks and gardens. He had spent the week in Dublin, and, with the kind assistance of their courteous secretary, Mr. Backhouse, he had had a rare opportunity of visiting a great number of places of engineering interest, not the least of which were Messrs. Guinness's great works, where their engineer, Mr. Forsyth, whom he was pleased to see present that evening, had been very attentive in showing him round the splendid fire-proof buildings recently erected.

He was sure the buildings in Dublin were most ornate and worth a visit from any English architect, whilst many of the societies and other scientific institutions were fully up to those of London. In fact, he did not think Dublin was behind in anything that might be necessary to make

it beautiful, and an inspection of that splendid block of buildings recently erected for the better housing of the working classes would convince even the most critical that due attention has been given to health as well as beauty.

He must congratulate the Institution in having as President Mr. Robert Cochrane for the second year. In him they had an excellent President. He wished to offer his congratulations both to the Institution and to Mr. Cochrane. He felt it a great honour to have read the first paper in the President's second year of office. The Engineers in Ireland had an Institution building, with lecture hall, library, and other equipments worthy of the profession, and they certainly had a good President, who would fully maintain the good record which the Society has enjoyed ever since its establishment in 1835.

He hoped the paper he had read would be of service to engineers. Most of the subject dealt with work actually carried out, but, perhaps, the most tedious and possibly the most uninteresting portion of the paper was that part dealing with cements and concretes. Every engineer who has used concrete must admit that there is a right and a wrong method of making this material, and that the correct gauging and selection of proper materials are matters requiring experience and care. The addition of trass to the cement for works of sea defence in some cases appeared to be an advantage in the long run. Although its benefit may not be apparent at the early stages of the work, its counteracting effects on the injurious nature of free lime in cement may in the long run be a considerable advantage; besides it, curiously enough, appears to turn that pernicious substance to good account.

He was very sorry that Mr. Dick was unable to be

present, because there were one or two points in the paper he would have liked to hear him speak on. He had for the past two years carried on an interesting correspondence with Mr. Dick regarding the power of the sea and the waves' action upon sea-walls and other structures—something similar to the point raised that night by Mr. Purcell. Mr. Dick's theory appeared practical, but although he had had three dynamometers made especially for the purpose of testing the practical value of the theory he had so far been unsuccessful in getting a right sort of storm at the same time as the instruments were in position and in working order. Mr. Dick is of opinion that the power of the sea exerts its force in straight lines with the object it attacks in the place of parabolas, as contained in his paper on the "Design of Breakwaters."* So that if they could ascertain the maximum specific force of the sea at the three points constituting the triangle they would be able to arrive at the relative maximum power of the sea at any point of the sea coast by simple mathematical formulæ.

He would take this opportunity of wishing Mr. Dick Godspeed and every prosperity in his new sphere. Mr. Dick had for some years held a most important and responsible position as engineer to the Board of Works of Ireland, and although they must all regret losing him and his close interest in the work of the Institution they were pleased to see how well his past work had been appreciated, as evidenced by the advance he was now making as a Government official.

Mr. Kernaghan had made some reference to a wall he had constructed in Ireland with success, and referred to the undermining of another sloping wall. This question

* "Notes on the Design of Breakwaters," by F. J. Dick, M. Inst. C.E., read before the Inst. C. E. Ireland, 1902.

opened up an important matter in the Penzance wall. The weight of the wall in question is carried—as will be observed by the section—on the solid killas, behind the front apron. The front apron of concrete and granite protects the rock from the erosive action of the beach stones and sea, but the weight of the superstructure is in no way dependent on the front masonry. So that should the wall at any time become undermined there will be little or no danger of settlement, and courses of masonry could be built in under the present foundation stones at comparatively small cost.

He could not give a satisfactory answer to Mr. Purcell's question regarding the power of the after-push of the sea waves. It appeared to him that the power of the sea must be calculated from the moment of impact to the finish of the "follow-on." It is a continuous force until the wave returns. The dynamometer, as at present constructed, recorded only the maximum force, but that maximum force is all the more severe owing to the duration of that force. He wished he knew a little more about the subject to explain it better. He, like many other engineers, often felt he was getting out of his depth in endeavouring to arrive at something definite regarding the action of the sea.

He thanked Mr. Ryan for his kind remarks, and hoped before long to be able to again visit Dublin for the purpose of reading another paper and enjoying their friendly hospitality.

N.B.—Appended is a copy of letter received by the author from Mr. Dick, which forms equally a supplement to his own paper, "Notes on the Design of Breakwaters,"* as to this:—

* "Notes on the Design of Breakwaters," by F. J. Dick, M. Inst. C.E., read before the Inst. C. E. Ireland, 1902.

"I am led to the conclusion that the force diagram should be composed of straight lines rather than of parabolas,* and that the zero pressure below should be taken at a depth of two and a half times the wave height instead of twice.* I think a fair depth for wave velocity in the Penzance case would be that at 250 feet from wall—viz., 16 feet. This with 5 feet wave gives $13\frac{1}{2}$ feet as depth below trough of wave, and the calculation of pressure at mean level of wave (H. W. S. T.) would stand as follows:—

$$V = \sqrt{2g\,(\tfrac{1}{2} \times 13\tfrac{1}{2}) + (\tfrac{3}{4} \times 5)}$$
$$= 8{\cdot}02\,\sqrt{10{\cdot}5} = 26 \text{ ft. per sec.}$$

Allowing for rapid shoaling and occasional interference, this velocity should in this case be multiplied by 1.80, giving an occasional maximum velocity of attack of 46.8 ft. per sec., for which the corresponding value of it is 34.2 feet.

Force of mean level of wave is:—

$$\therefore \frac{2 \times 34{\cdot}2 \times 61}{240} = 1{\cdot}95 \text{ tons per sq. foot}$$

and taking zero force at $2\frac{1}{2}$ height below H. W. S. T. the force at dynamometer 7 ft. below H. W. S. T. is

$$(12\tfrac{1}{2} : 5\tfrac{1}{2} :: 1{\cdot}95 :)\ {\cdot}860 \text{ ton} = 1930 \text{ lbs.}$$

The force actually recorded being 1,980 lbs."

* "Notes on the Design of Breakwaters," by F. J. Dick, M. Inst. C.E., read before the Inst. C. E. Ireland, 1902.

[1st February, 1905.]

Mr. Robert Cochrane, I.S.O., President, in the Chair.

The following candidates were balloted for and duly elected:—

Lucius J. Boyd, as a Member.

John C. Wilmot, as an Associate Member.

The Closing of the Breaches on the Myroe Embankment, County of Londonderry.

By Mr. Berkeley D. Wise, Vice-President.

Previous to the occurrence of the great storm of the 26th and 27th February, 1903, a southerly wind had been blowing round the North of Ireland for upwards of a week, which, to a certain extent, had raised a high sea round the coast. The wind then changed to the north-west during the time of high spring tides, and blew the sea up into Lough Foyle, thus raising an abnormally high tide in the Lough. On the 26th the wind rose to almost a hurricane, and, suddenly veering round to the south-west, blew with its full force against the Myroe Embankment. From eye-witnesses the water was seen to be playing on the top of the bank for a distance of about half a mile, the foam from the gale flying over the top of the bank.

The first breach which showed itself was made on the morning of the 27th, in the canal bank, and occurred about 7.30 a.m. It was 80 feet wide and about 6 feet deep in the centre. The main breach occurred in the sea bank about half an hour later, and speedily became 100 feet wide and 8 feet deep in the centre. When the banks broke the tide was just about to ebb, so that the full extent

of the flooding was not apparent until the next day, as it took the two succeeding tides to fill up the land, which lies about three feet lower than the foreshore outside. The area flooded was 753 acres, and about two and a half miles of the railway was submerged to a depth of nearly 3 feet at every high tide. All the farmers and labourers in the intake had to leave their houses—91 persons being rendered homeless. The railway passes over the top of the embankment adjoining the River Roe, then drops down to the reclamation level by a gradient of 1 foot in 250 feet, and runs level with the surrounding fields until close to Limavady Junction station, where it again rises to go over the canal bank, which it crosses by means of a girder bridge, and then descends into the next intake. The rails were covered at every tide, necessitating the use of a pilot engine with all the trains. The greatest depth recorded was about 3 feet 4 inches over the rails. The trains were constantly running with the lower footboard under water. Steps were immediately taken to raise the line, and during the months of March and April it was lifted an average height of 3 feet for two and half miles. This was a work of great difficulty, as the tides crossed the line twice every twelve hours. The raising was done almost entirely on road metal. The only delays that occurred to the traffic happened on two or three occasions, when trains were kept waiting for two or three hours.

Owing to financial difficulties, which it took several months to overcome, nothing was done towards repairing the breaches, which had, owing to the action of the tide, been scoured out much wider and deeper, especially the breach in the sea embankment. The water now accumulated inside the embankments, driven by south-westerly and south-easterly winds, and took most of the back out of the bank, which was composed of soft material, for the

major portion of the whole embankment, causing extensive slips.

After a considerable amount of negotiating, a sum of £3,750 was raised to restore the embankment—the Irish Society subscribing their money on condition that the Northern Counties Railway Co. would undertake the work. The Company, however, refused to accept any responsibility in the matter, and finally, after the whole summer had been allowed to pass, the Irish Society consented to give their subscription provided the writer would act as engineer.

In the month of June following steps were taken to commence the repairing of the worst minor damages in the pitching of the sea bank and close the breach in the canal bank. This breach was first about 90 feet wide and 8 feet deep, and a large hole had been scoured out extending the full width of the gap, and running into the field about 100 feet, roughly semi-circular in plan, and 20 feet in depth.

The plan which was adopted was to fill sacks with the blue mud from the foreshore, and place these in rows across the gap when the water was at its lowest. Owing to the narrowness of the embankment it was impossible to get materials to the site by means of tramways.

Flat-bottomed boats were constructed to carry four to six tons, and drawing about 2 feet of water. As the tide ebbed the flats were anchored in suitable places in the canal and filled with the surrounding blue mud. They were then poled to the gap, the mud put into bags, and dropped in where required. The bags were placed about 15 broad at the bottom, decreasing to about 4 broad at the top. They were placed in layers across the gap.

As soon as the bags commenced to appear above the surface of the water loads of blue mud were filled up on both

sides of the core of bags. This was finally brought to the proper height, and found to be perfectly water-tight. The face of this bank was then pitched, and the back sodded.

Main Breach.—When the operations for closing the main breach commenced in August the opening was 127 feet wide and 23 feet deep in the centre. A large hole of the shape shown on the plan had been scoured out. The front, side, and edges were almost vertical—the water varying from 12 inches to 12 feet in depth in less than two yards. The field end was not quite so steep. On each side of this breach the embankment was severely damaged, particularly on the north side, the top having been washed down about 3 feet for almost 300 yards. There were also a couple of slips on the south side, each about 100 feet long, likewise caused by the storm.

Several suggestions were made as to the proper way to attempt to close this breach. It was proposed to run a row of piles across the breach in line with the old embankment; others thought that a filling-in on both sides was all that was required, but the writer consulted Mr. William Kernaghan, a member of this Institution, who has had great experience in the closing of such breaches. He gave it as his opinion that no attempt should be made to close the breach in a straight line, but that a coffer dam or bank should be made round the breach on the slob-land. Mr. Kernaghan's ideas were to a large extent carried out. It was also suggested that the large area of 753 acres should be divided into two, by making an embankment from the railway for about a mile and a quarter, so as to divide the area of water into two portions, and deal with one portion at a time. However, as it was utterly impossible to raise sufficient money to carry out such a scheme, that idea was abandoned. It was not a very practical one in any case, as there would have been the very same diffi-

culty in closing that bank that would be experienced in closing the sea breach. The engineer who made this suggestion contemplated running a line of railway across the embankment in order to get material to the main breach. Before the main breach had been closed the whole of the money would have been spent, and only half the area drained.

It was then, after due consideration, ultimately decided to construct a coffer dam of a length of about 1,000 feet. The first intention was to make this a temporary structure, and remove the residue of the water from the interior by means of steam pumps, and then make up the bank on the old lines.

This might have been a cheaper scheme, but there was a very great risk of damage being done to the temporary coffer dam during construction.

I finally decided to make a circular coffer dam, using it as a core for the permanent bank, and abandoned the thought of closing up the old bank.

The foreshore is covered with a grass-like seaweed, too soft to walk upon, and is dry at low tide, except for a narrow belt next the embankment, about 100 yards in width, which lies about 18 inches lower, and is always covered with water. Although the new embankment is now left dry at low water, except for the belt mentioned above, yet when the piling was in progress, even during very low tides, the water from the intake was ebbing out over the slob, varying in depth from 16 inches in spring tides to 4 inches in neaps—often too shallow to allow anything to float out to the piling machine owing to the seaweed, and yet too deep to permit of planks being laid down to walk on. This proved most awkward during the whole time the piling was in progress, and made it very difficult to get piles to the machine at low tide.

When the tide was flowing inwards or outwards it was very difficult to keep the boats alongside the work.

From local information it was thought that the blue mud was of unknown depth, gradually getting stiffer and becoming blue clay, and would be a good foundation for the piles. Instead of this, it proved to be only about three feet thick, except for short distances, and underneath was found a bed of sand and shells, which were carried away with the slightest current when the top was removed.

The coffer dam was composed of two rows of 12 inch by 6 inch pitch pine piles, 7 feet apart, and 12 feet centre to centre and 12 feet long.

The bank is 960 feet in length, with 79 whole and 2 half bays. The piles were driven with their 12 inch faces in front elevation. 6 feet by 12 inch by 6 inch pitch pine foot blocks were hand driven 4 feet deep, 5 feet away, centre to centre. On the outside of each outside pile, and on the inside of each inside one, two 9 inch by 3 inch stays were nailed from each foot-block to its pile. Two cross heads 10 feet by 9 inches by 3 inches were fastened across each pair of pile heads, projecting 1 foot 3 inches past the pile on each side, as shown on drawing. The sheeting, 12 feet by 9 inches by 3 inches, was nailed on the sea side of both rows of piles, the foot-block stays of the outside piles having been removed. The sheeting on outside piles was originally nine planks high, a tenth being added later on. This made the top of the sheeting level with the top of the piles. The six bottom planks on the outside were tongued and grooved, the remainder being plain. The inside sheeting was plain, eight planks deep from the underside of the cross heads. Intermediate planks, 10 feet by 9 inches by 3 inches, hand driven 3 feet into the mud, were nailed to the sheeting in the centre of each bay, on the same side as the piles. Sheet piling, 9 inches

by 3 inches, from 3 feet to 6 feet long, depending on the depth of the mud, was hand-driven into the hard sand level with the top of the lowest plank of the inside sheeting, and nailed thereto.

The Piling Machine and Piling.—Owing to the extreme shallowness of the water, and the strong current caused by the incoming tide running through the gap—frequently at a velocity of four miles an hour—it was found impossible to use a floating piling machine. The machine used ran on the tops of the piles previously driven on flange rails 30 lbs. per yard, spiked to 11 inch by 11 inch pitch pine logs, and was double, with a pair of leaders 7 feet centre to centre. The overhang was 12 feet. The arrangement proved very satisfactory, except that the great overhang rendered it impossible to work during a high wind. All the necessary machinery, timber, rails, &c., &c., had to be brought by train and loaded into the flat boats and poled down to the place of erection. The first two piles for the coffer dam were driven on the 7th August. A difficulty was experienced in turning the corners of the coffer dam with a machine having a projection of 12 feet.

The only mishap that took place in connection with the piling was on the evening of the 24th August. After 48 piles had been got in at the south end an exceptionally high tide occurred, and it was noticed that the grass on the slob was beginning to rise. There was a swift current running at the time, and the deep hole suddenly enlarged and came right up in a southerly direction, taking away a number of the piles. The blue mud was first swept off, and then the sand underneath, and a hole formed with the line of the piling, about 8 feet deep. It was decided to continue the piling round to the south side, and this work was carried out successfully, the length of the piles being increased to 16 feet, the height above the blue mud re-

maining the same. A new row of piles to replace those carried away was driven 60 feet further back from the hole, and an apron of large stones 2 feet thick and about 20 feet wide placed between these piles and the side of the hole. This resulted in the prevention of the approach of the hole to the new row of piles.

On the 30th September the piling was finished to the north bank. When the piles had been driven right round for the full distance, two 9 inch tongued and grooved planks were put on the outside of them, their top level being below low water mark as much as possible, and one plank was put on the inside of the piles, with its top at the same level. Small sheet piling, about 4 feet long, was driven in along the sea side of this latter plank, and fastened to these longitudinal planks. This prevented a scour taking place under the longitudinal planks. These planks did not come up above low water mark, and as soon as they were fastened three rows of sand bags were placed round the piles to prevent the tide from cutting the ground at their base. Another row of sand bags was dropped into the mud at the back of the sheet piling to prevent the material from getting through the sheet piles. This formed a box 7 feet wide and 12 feet long. It was about 18 inches deep, and the top of it was level with low water mark. This was filled in as quickly as possible, and sheeted over with corrugated iron plates 7 feet long and nailed to the longitudinal planks. The work in connection with this row of planks and corrugated iron was commenced on the 9th October, and completed on the 4th of November. The tide passed over this corrugated iron without carrying away the clay put into the coffer dam.

A steam grab, kindly lent by the Londonderry Harbour Commissioners, excavated the clay from the foreshore.

The flat-bottom boats which were constructed were 8 feet

7 inches long and 6 feet beam, and when loaded with 5 tons drew 24 inches of water, with a seaboard of 3 inches. The hold was 12 feet 8 inches long, 6 feet 5 inches broad amidships, and 5 feet 10 inches broad at the ends. They cost about £8 each, made of pitch pine keel and spruce sheeting, tarred and caulked, and proved most successful boats for the purpose.

On the 17th November the first tide was stopped from entering the flooded area. The coffer dam was divided into eight sections of eight bays each. Squads of men under a responsible person were allotted to each division, and at a signal each squad simultaneously put on a plank, with the grooved side upwards, along the bays of their divisions. Two men handed up the planks, two nailed them on, and two more packed the bottom with stones and seaweed. As soon as the men in each squad had their planks nailed on, they climbed on top of the piles and waited until the signal was given to start another row. Each row was finished complete from end to end and all the men on the top before the signal was given to commence the next row. Four rows of planks were completed in fifty minutes, and the corrugated iron replaced. In all 3,110 superficial feet of timber was nailed to the piles in sixty-five minutes. The seaweed caulking proved most satisfactory, very little water getting in. The filling in of the coffer dam was started next day, when six or eight bays were stripped, the corrugated iron removed, and the sheeting put on the full height on both sides. It was then filled in four boards high. The average day's work, with fair weather, was 144 feet—the greatest care being taken always to keep the sheeting the full height as each tide passed over, thus preventing any scour.

On the 7th December there was an exceptionally high tide with a strong breeze, which caused the waves to wash

a little over the top of the coffer dam. To guard against this another plank was put round.

The pitching was commenced on the 4th December, and the stones for this portion of the work had to be brought in boats for a distance of about a mile and a half from the railway.

The whole of the pitching of the new bank was finished on the 11th March. A large amount of material for the completion of the bank on the inside was excavated from the slob. When this dried it became very solid, and perfectly watertight.

On the 10th March the filling of the new bank was finished, thus successfully terminating a work which had caused much anxiety in its earlier stages.

The damage done to the inside of the embankment by the east and south-east winds entailed a considerable amount of labour.

As soon as the main bank was completed the writer withdrew from the work, and the farmers themselves completed the repairs of the remainder of the bank.

The work was originally in charge of Mr. J. B. Wise, the writer's son. He left on the 5th August to take up a more important position, and Mr. W. K. Wallace was in charge until the completion of the work.

The rates of wages paid were:—Ganger, £2 per week; assistant ganger, £1 2s. 6d.; boat contractors, £1 2s. 6d.; boat men and machine men, 16s.; and labourers, 15s. During the entire period no accident of any consequence occurred in the carrying out of the job, and the successful termination of it reflects great credit on those in charge.

It is interesting to state that all the hedges, trees, and vegetation were absolutely killed by the salt water, but the crops of the first season since the flood have been better than was anticipated.

The total cost of the work was £3,600.

[1st March, 1905.]

MR. ROBERT COCHRANE, I.S.O., President, in the Chair.

The following candidate was balloted for and duly elected:—

SAMUEL SHAW, as an Associate.

ON THE USE OF PHOTOGRAPHY FOR RECORDING CONTINUOUS SOUNDINGS DURING PROGRESS OF RIVER, CANAL, HARBOUR, OR ESTUARY EXCAVATIONS (Part II.).*

By JAMES DILLON, Past-President.

IN recent years the development of science, the increase in commerce, the enormous increase in the carrying trade is due in a measure to the different countries being covered by a network of railways, along which the produce of each country reaches her seaports, there to meet ships of great tonnage.

It is obvious that the harbour accommodation throughout the world that was found sufficient before this great increase of commerce set in will from this out prove wholly insufficient, and that a large increase of work will necessarily be thrown on hydraulic engineers in designing and providing harbours and waterways.

The great increase in the drafts of ships and boats of all kinds for the reasons above stated necessitates a corresponding increase in the waterways in nearly every country throughout the world, particularly as regards the depths of their waterways, which in some countries now exceed depths of 40 feet even for harbours and estuaries.

To meet these great demands colossal dredging machines of greatly improved construction, including the

* For Part I. see Trans. I.C.E.I., Vol. XXVII., 1898.

bucket dredgers, suction dredgers, and other types, are now being sent from England to different parts of the world, the actual cost of some of the larger types exceeding £10,000—the volume of work turned out monthly by such huge and costly machines far exceeding what was dreamt of in former times, and even in recent years.

I need only refer to the new deep water channel now used by the great Atlantic liners through the Liverpool sand bar at low tides.

When carrying out such immense excavations, sometimes exceeding depths of 40 feet below sea level, it is essential that no unexcavated portion of the old harbour or sea bed, no matter how small in height, should be allowed to remain standing above the new revised level of the newly excavated river or harbour channel.

Ships drawing 40 or more feet of water entering a newly excavated channel, where unexcavated portions of the old sea or harbour bed escaped detection, might lead to enormous loss by the partial destruction or sinking of a ship by striking on a rocky or other unexcavated portion of the new sea bed.

It is known to hydraulic engineers that accidents of this kind are of frequent occurrence, so much so that it is now universally admitted that more care must be taken when sounding and testing the new excavations, and that a good workable continuous sounding machine—one that could pass over no submerged obstruction without indicating it to the engineer engaged in testing the soundings—when put on the market will be extensively used if not too costly to make, work, and maintain.

Such a machine would be useful when preparing surveys of proposed river or harbour excavation works, and for testing same during and after their completion from time to time.

In past years had such a machine been in use much litigation and its cost would have been avoided, and there are eminent engineers still living who, if they cared to publish it, could tell of the enormous financial losses they sustained, arising out of accidents of the kind above referred to, through unexcavated material striking and damaging ships below sea level, &c., resulting in the owners of the ships plunging into litigation and obtaining heavy verdicts for damages from the harbour boards, &c., having charge of the works, in some cases the boards seeking damages from their engineers, who erroneously certified to their boards that the new excavations were fully completed, no doubt believing them to be so completed, and wholly unaware of any unexcavated portions of the old sea bed having escaped the attention of those in charge of the excavations.

I do not propose to lengthen this paper by referring in detail to the continuous sounding machines I have read papers on, in this country, America, and elsewhere; but the following is a correct list of the patents Her Majesty's Patent Office was pleased to grant me in the following years:—

A.D. 1881—8th August, No., 3,418.
„ 1885—22nd August, No. 9,969.
„ 1889—24th October, No. 16,817.
„ 1893—21st October, No. 19,845.
„ 1897—21st October, No. 24,347.
„ 1901—21st October, No. 21,046.

It will be observed I preserved my patent rights by only allowing an interval of time of four years between each patent.

Perhaps I should here state that more or less full descriptions of the above patents, except the two last I am about to deal with this evening, will be found in

papers read by me in the following volumes of your "Transactions"—viz., Transactions of the Inst. C.E.I., Vol. XVI.. page 71, in 1886; Transactions of the Inst. C. E. I., Vol. XXVII., page 1, in 1898, in which will be found a description of the machines for which I was awarded the International Gold Medal by the Commission presided over by the Prince of Wales at the London International Invention Exhibition.

On this occasion I will endeavour to describe to you my automatic high-speed sounding machine for taking continuous soundings at speeds greatly in excess of what has hitherto been accomplished, so as to enable the engineers on a "rising" or "falling tide" to run in a very short period of time numerous lines of soundings parallel and, if necessary, at right angles to each other during "high," "low," or "half tides"; and should I succeed in photographing on a photographic film roll each line of soundings or a series of soundings taken on a given date, then by taking a similar series of soundings in the same way and over the same ground at the end of a week, month, year, or years, and in a similar way photographing each new line of soundings (the soundings being photographed to a scale of feet and inches), then by placing the most recent photograph over the former one the difference in depths in feet can be read off, and when multiplied by the length and breadth in feet and divided by 27 will give the number of cubic yards dredged or removed out of the new river or harbour excavations during the interval of time that has elapsed between the date of the first and second line of soundings.

This high-speed sounding machine is designed to provide a simple and effective apparatus for indicating at a glance and recording, if found desirable, the depth and variation of depth of water in seas, rivers, harbours, lakes

and the like and is intended to improve and simplify the apparatus described by me in former papers read before your Institution, and also to provide means whereby a series of soundings may be photographed in succession upon a continuous photographic film, showing also the speed of the vessel and the year, day, hour of high water (if tidal) and hour in which the sounding was recorded, thus admitting of comparison with ancient or other charts, tidal records, and ancient water channels' depths and the like.

In carrying out my said invention I have designed a self-contained sounding machine with all its parts complete and forming one whole so as to admit of it being attached to or removed from any steam or other boat, thus avoiding having to construct any special form of steam or other boat on which to work the machine, which may be called a sounding ladder.

The machine is made as follows:—I take two pieces of galvanised tubing, about 25 feet or more in length (each piece may be made of short lengths screwed together).

The two tubes are bolted together at the top, but are spread out to a foot or more at bottom, where they work on an iron axle.

Two similar tubes of about same length work on this same axle, hanging from it but in an opposite direction and under the first-mentioned tubes.

This axle is pivoted to a third galvanised tube of about equal length (or it may be longer or shorter); the other end of this tube admitting of being hooked or pivoted to the side of any steam or other boat before using the machine.

This tube may or may not be rigidly fixed to the boat as circumstances may require with three or more steel

or other wires in such a way that the machine may be shipped or unshipped at a moment's notice by the engineer in charge.

This tube is used for all soundings up to about 20 feet and when the depth to be sounded exceeds 20 the immersed end of this tube becomes the centre on which the remainder of the machine works, when indicating soundings exceeding 20 feet.

Bell or other wire is passed through all these tubes to be actuated on by levers (when the machine is working) to indicate depth of soundings.

At the top of this combination of tubing I attach a square board painted white, placed in a diagonal position, the surface of the board being vertical.

In this board I cut a vertical slot; at the side of this slot I put a scale of feet; and at the side of this scale in small circles I insert date of month, hour of high water, a time piece and other required information to be afterwards photographed, when photographing the soundings (if required by the operator).

In the vertical slot or groove adjoining the circles I place a black button working vertically to scale, which rises and falls up and down the board as the depth of the water increases or diminishes, under the sounding ship, this black button being worked by a lever effected by the rising and falling of the trailing end of the sounding ladder on the undulating sea bed, the levers being connected by the copper wires.

All these movements and dial records being in a vertical plane can be photographed on a roll of photographic paper or other substance in the ordinary way, each exposure being only $\frac{1}{8}$ or more inch in breadth, the number of exposures depending on the will of the operator at certain intervals of time agreed upon, or at certain dis-

tances traversed by the ship as defined by her log dials, or fixed points on shore, or defined by a paid out measuring wire or by angular measurement from off or on to the shore.

In this way, after 100 or more photographs are completed on the paper or film roll, a pencil line drawn through the photographic impressions of the black button that represents the depth of each sounding will give the contour of the sea bed at each point of observation, while there is also recorded the exact hour of observation and date and hour of high water (if in tidal waters).

This sounding machine designed for soundings of about 40 or more feet can be made to fold up so as to suit lesser depths of about 20 or more feet, by pulling up the lower half of the sounding ladder and folding it back on the upper half, and freeing the wire ropes fixing it to the ship, then the folded sounding ladder trails along the shallow sea bed, the upper part being pivoted to the ship's side, above water level; this arrangement will work up to speeds of 5 or more miles per hour without any tendency to rise from off the surface of the undulating sea bed, but it can be worked at much higher speeds when the whole ladder is opened out and working on its middle pivot.

On the white square board I bolt a triangular frame and attach to it by staples or otherwise a triangular tube, one side of which at least is composed of glass, and contains sufficient coloured liquid to fill one arm, the three arms being continuous throughout and hermetically sealed; the frame is so adjusted that when the maximum depth to be sounded is reached one side of the triangle is filled with water to its maximum, indicating the maximum depth, while the other two sides of the triangle are clear of water.

With the aid of this sounding ladder I can, when the ship is in motion, signal to observers on shore or in following ships, the water depths under the sounding ship, by pivoting a semaphore signal to the ship's mast and connecting the semaphore with the sounding ladder.

A drawing of the surface of the sea bed according to scale can also be obtained by any of the well-known methods, by using clock-work to move a paper roll in contact with a lead pencil or other metallic pointer, the pencil to be actuated by a lever connected with the sounding ladder, and as the trailing end of the ladder rises and falls with the undulating surface of the sea bed, so will the lead pencil rise and fall while drawing the contour line of the sea bed on the paper roll to the required scale, the latter being determined by wheel gearing or other well-known methods.

I may use any one of my devices separately to ascertain the depth of water, or may employ any two or more of them together, and to ensure perfect accuracy of calculation may take the mean of two or more simultaneous soundings as may be required for civil, military, naval, or other engineering purposes.

Figs. 1 or 1A is a view of the sounding machine with all its parts complete as shown by the black lines, and the dotted lines show how, by the use of ordinary wire rope, the machine can be attached to the ordinary form of ships or boats propelled by mechanical or other power.

Fig. 2 is a view of the same machine when attached to a boat and looking aft—the dotted lines showing the position of the wire ropes for keeping the machine in its proper place.

Referring to Figs. 1 and 1A, A.B. is an axle on which works two lines of tubes C.D. and E.F. like telescope tubing, so as to admit of their total length being increased or

diminished; two lines of similar tubing G. H. and I. J. hang from the axle A. B. Metal sliding rods worked like a ship's topmasts could be substituted for all this tubing, admitting of the machine being lengthened or shortened as required. On top of the tubing C. D. or rods is placed a white triangular or square board K. L. M. and attached to tubing or rods by angle iron at K.

In this board is sunk a triangular glass tube containing sufficient coloured liquid to fill only one arm of the triangle; the tube being continuous and hermetically sealed. Outside and adjoining the glass tube are placed scales of feet; on the upper side of the tube are placed three circles—one contains a clock or time piece, another the hour of high water, and the third circle the day of the month and year the operator is working. Similar scales, circles, and figures are put on both sides of the board K. L. M. N.

Attached to the lower end of the axle A. B. is a tube O. P. in three parts, to pull out like a telescope tube.

This tubing can be pivoted to the side of any ship at Q. and kept in this position by the rope R. S. Attached to this tubing near P. is another triangular glass tube together with scales of feet *j. k. m.*

The machine can be attached to any boat by using for the purpose the wire and ropes T. A. U. Fig. 1 and Y. V. W. X. Fig. 2, thus enabling the axle A. B. to work on a fixed centre at its end A.

Having adjusted the different lengths of tubing shown in Figs. 1 or 1A—to suit the size of the boat and the maximum sounding likely to be required—the boat is moved into deep water to mark a scale of feet near L. K. and K. M., and the tubing G. H. is drawn up by the rope at Z. into a horizontal position. The exact depth of the end H. below surface of the sea is thus ascertained by a suit-

able measuring tape. Then as the operator allows the end H. to drop below the horizontal 20, 30, or more feet he marks the figures 20, 30, or more feet on the scale K. L. N., according as the coloured liquid in the triangular glass tube K. L. N. rises in the arm owing to the tubing G. H. and C. D. both working on the same fixed centre at A. The scale of feet thus marked at side of glass tube will last for months or years and refer only to the depth below the fixed centre at A.

The triangular water scale *j. k. m.* fixed near the end P. of the tubing P. O. is marked on the same principle by releasing the wire rope T. A. and drawing the end O. of the tubing P. O. to the surface of the sea; then as the operator drops the end of O. of the tubing P. O. below the sea level, 1, 2, or more feet, the water rises according to scale 1, 2, or more feet in the right hand arm of the triangular *j. k. m.* scale near P., when the figures can be permanently marked on the white scale and will remain correct for the particular boat used when marking the scale. The figures are painted on both faces of the board *j. k. m.*

When taking soundings the boat is propelled forward, and the resistance of the water tends to press downwards the tubing C. D., which is now working on a fixed centre at A., while the same motion tends to press upwards the tubing G. H.; thus the total weight of the whole tubing causes the trailing end H. of the tubing to keep in close contact with the sea bed, and as it rises and falls with the undulating sea bed it causes the triangular glass tube at K. L. N. to rock forward and aft, thus causing the coloured liquid in the triangular glass tube to rise and fall according to scale 20, 30, or more feet, corresponding exactly with the depth of the water through which the boat is passing. This arrangement of the tubing is for

taking soundings ranging from 20 feet below surface of water to sea bed—some 40 or more feet below surface. Same depths are indicated by black button at *r.*, connected by spiral spring and bell wire through tubes C. D. to *i.* and fastened at *h.*, due to the rocking of the tubes fore and aft on fixed centre A. For the way in which indicator is worked see Fig. 1, where indicator *r.* is pulled down by a spiral spring and pulled up by the bell wire passing over wheel near M. and entering tubes C. D. at D., passes out of them at i_n and then fastened at *h.* to tubes P. O. To take soundings from sea surface to 20 feet below it, the tubing G. H. and C. D. is folded back on the tubing P. O., the wire rope T. A. is released, thus leaving the weighted tubing P. O. to trail along the sea bed, and as the latter shoals towards surface of the sea, the end O. of the tubing rises from a depth of 20 to 15, 10 or 5 feet, thus causing the water according to scale to stand at 15, 10 or 5 feet in the triangular glass tube *j. k. m.* fixed to the tubes P. O. Thus the operator has only to note the rise and fall of the coloured liquid in the glass tubes, recording in his note book the figure on scale to which the colour liquid rises or falls to.

TO PHOTOGRAPH THE SOUNDINGS

by any of the well-known methods, a wide angle kodak (see Cross No. 4 of Fig. No. 3) with film roll is attached by angle iron bracing close to and opposite the boards containing the scales for water depths (see Fig. 3), and the circles in which are placed a time piece, day of the month and year and hour of high water. At whatever intervals of time or distance the operator decides upon photographing the indicated depths of water in the glass tubes he touches a button on the kodak and a photographic impression is taken of the depth of the coloured liquid in the

glass triangular tubes and the hour of high water, and the year, date, and hour it was taken. (See photographed soundings, Fig. 5.)

The breadth of this photograph need not be more than one-eighth or one-quarter inch—its height corresponding to the breadth of the film roll. In this way the operator on completing a line of soundings, their position being defined by angular measurements or otherwise from off shore, temporarily places a letter or number at the side of the glass tube before taking the last photo of the series, and then both are photographed—the letter or number indicating the last of a particular line or series of soundings. When another line or series of soundings are commenced, and photographed on the same film roll, and so on, until the whole length of the film is used up with little narrow photos one-eighth or one-quarter inch in breadth of the glass tube, showing the depth or height of the coloured liquid in the tube. (See Fig. 5.)

It only remains for the operator on developing the photos and completing same to draw a pencil line through the top of the photographed water depths to represent the undulating sea bed surface. (Fig. 5, allowing for the rising or falling of the tide when necessary.)

By a comparison of a series of sections taken at intervals of weeks or months over the same ground, the amount of silting or dredging can be determined or the amount of scouring.

By placing the tubing G. H. in a horizontal position and with the aid of a measuring tape letting it down, one, two or more feet below the horizontal, total depths of trailing end becomes known and is figured with a chalk on top of deck rail behind tube C. D.—then a scale of feet is obtained on top of deck rail from *p.* to U. Similar results could be obtained for depths up to 20 feet (if from

any cause the triangular glass tube at *j. k. m.* happened to be broken) by using a weighted pendulum *f.* working on a centre at *e*, and pointing to the depths in feet on the quadrant *g* when the end O. of the tubing P. O. is allowed to trail along the sea bed.

Fig. 6 represents a river sounding-tube suitable for soundings of 20 or more feet.

THE PRESIDENT said he wished, in the name of the members, to thank the author for the very interesting paper he had produced for them that evening at very short notice. They had been promised two papers, one of which was to have been read that evening, but, almost at the last moment, within the last few days, they heard that the promised paper would not be forthcoming. The author had, therefore, very kindly consented to come forward and fill the gap by reading this paper. It did not follow that because it was prepared at such short notice that the author had not given the matter very great consideration. They could see that the subject he had brought before them was one that must have engaged his attention for a very long time (between 1881 and 1905), and he had given them the results of his experiments and extended experience covered by six different patents.

With reference to the improvements the author had made in his sounder since he first introduced the matter to the Institution some years ago—these experiments had been very great, and he considered the most important was the increased rate of speed at which the soundings could be taken, and the very ingenious manner in which it was proposed to record those soundings by photography. He considered this was a very clever method, and one that was likely to be utilised by engineers who required to make use of soundings of that

nature. As it was obvious that owing to the great increase in the size of ocean-going steamers, &c., of late years a large proportion of the harbours throughout the world must be increased in their depths, and some such machine as the author has described will be required to test the new depths, Continental engineers have copied parts of this machine.

Mr. Wm. P. Moore said that he did not propose to criticise the paper, but rather to give a description of the ordinary method of taking soundings in the Port of Dublin. These soundings are taken with a chain of brass wire having a lead sinker. Each link is 3 in. long, and each foot is marked with an engraved label up to the maximum depth expected, say 40 feet. In the upper part of the harbour where a berth is to be sounded the quay-wall is marked off at even distances, say 20 feet apart, and lines of soundings are taken opposite each mark at right angles to the wall. The distance of each sounding from the wall is measured with a rope, one end of which is fast to the wall and the rest coiled in a boat. The rope is marked at 5 or 10 feet intervals. Two men row the boat slowly, one man attends the measuring rope, and another sounds with the chain as each mark is reached. A fifth man, who is the official in charge of the operation, keeps a record in his note-book of the depth and position of each sounding. He also takes a note of the height of the tide on a tide-gauge, which is simply a board with feet printed on it in figures six inches long. The gauge is nailed temporarily to the quay wall with its zero corresponding with the Admiralty low-water level. The soundings are subsequently plotted, each in its right place, and with the depths reduced to standard low-water.

Below Ringsend the South Wall is marked with large

square white marks, spaced 120 feet apart. Each mark corresponds with a line of soundings on the chart. The boat here is rowed by four men, the white mark being kept in line with the Two Rock Mountain. No measuring line is used, but a note is kept as certain cross-bearings come into line. The soundings are taken at as uniform a distance as possible, and are plotted on the chart by dividing the distance between any two ascertained points by the number of soundings taken between those points.

Further down the river the Sugar Loaf Mountain is used as a back sight, but in the Bay outside the lighthouses the lines of soundings are run from east to west. The various lighthouses and beacons in the river and chimneys on shore being utilised for keeping the range of the line. The positions on the line are found by taking angles with the sextant to objects at Sutton or Kingstown. In these outer soundings the height of the tide is taken by independent observers at intervals of five minutes, and the man sounding takes a note of the time he begins and ends a line of soundings.

High-water is the time generally chosen for sounding, as the surface of the water is then practically level and there is little current, but in the upper part of the river low-water time has the advantage that there is less interruption from steamers passing to or from the docks.

Whether soundings are taken as described or with Mr. Dillon's apparatus it will be necessary to correct each sounding for tidal variation, and also to plot it in the correct position on a chart.

Mr. Allanson-Winn said he would like to ask the author how he arranged to pull up the lever rod when he got into shallower water; for instance, when approaching the shore. This sounding apparatus was extremely

interesting to him, for he was just then engaged in taking a section of a shore below low-water level. He could not get sufficient information from the Admiralty charts and would be very glad of the assistance of some instrument which would take the soundings from, say, the five fathom line right up to low-water. It occurred to him that this instrument could only be used within certain limits, according to the depth that the boat would draw. He supposed there were runners at the foot of the arms to prevent undue sinking in the sand, or that the speed of the boat possibly got over that difficulty. He thought if they were using it in muddy rivers and estuaries they might find the runners sinking about one or two feet in the mud from the weight of the rod.

He would like to know what was the approximate cost of this apparatus, as he was anxious to get an instrument that would enable him to sound from a ten fathom line up to within three or four fathoms, as this would be a great advantage, and it would then be easy to take the remainder of the soundings in the ordinary way or with a graduated bar.

Mr. J. H. Moore said he would like the author to tell them in what harbour or river works this machine had been actually used.

Mr. Tomlinson said he had some experience of soundings and he did not altogether agree with all the author claimed for his apparatus. The idea of the trailing bar appeared to be a good one, but he considered the author was wrong in his calculations.

The trailing bar was pivoted on a fixed point, and the depth of the water below the point of suspension divided by the length of this trailing bar was the sine of the angle made by the spar with the horizontal line.

It seemed to him that the author in his diagrams

assumed that the actual height of the column of coloured water which was found in the glass tube was directly proportional to the depth of the water. He doubted that. It did not seem to him to be correct. If it were not correct then the scale must be unevenly divided, and the section plotted photographically can be only regarded as a record and cannot be worked from as a natural scale.

Mr. Dillon, in reply, said he would like to learn more about the machine referred to by Mr. Purcell. He had never heard of it before, and he would like to see how the cost would compare with his machine. From Mr. Purcell's description it seemed more suitable for deep-sea navigation.

With reference to what had been said about the accuracy of the water scale and the glass tube, there was no uncertainty about this at all, for, as he had previously described, there was no scale when he began to fit up the apparatus. He had only the triangular tube with as much water as would fill one arm only, and the scale of feet was marked at side of water tube as the bar was lowered into the water one, two, or more feet. As he had mentioned in the paper, this rendered the scale absolutely correct, and it could be used over and over again at different times for years.

With the scale accurate, and showing the correct depth, it followed that when he was able to photograph the record that he would get a perfect record that would do for all time as a basis for future measurements.

He knew the idea was new, but he believed it was all right and suitable for large engineering or hydraulic works.

With reference to Mr. Moore's question as to where it had been used, to answer that he would tell them how he came to make the apparatus. He had about sixty

miles of river work, and the contractor was very fond of asking for a certificate for £1,000 or so on account at frequent intervals. He did not like to give these certificates, as he knew very well that the work was not done, so he used different forms of this machine and brought the contractor with him, so that he could satisfy himself and see how the work was progressing and what parts were not done. He found it very useful in dealing with contractors, as they could not dispute its accurate working.

The apparatus was originally designed for fresh water work, and he anticipated trouble when he came to use it in the salt water owing to the oscillation of the waves when he got into deep water. However, he got over this difficulty by altering a few parts of the apparatus and putting stays on the sides to overcome the oscillation of the waves, and by placing a fix centre attached to the ship at about half the maximum depth likely to be required the water resistance did not lift the sounding tube off the sea or river bed. He also used the machine in Kingstown Harbour with very satisfactory results.

He hoped some of the younger members would rig up one of these machines, and then they would be able to tell the members of this Institution a great deal more than he had done.

The cost of the machine was not very great. His whole aim had been to keep it out of the hands of the machine makers. It would be easy to make a machine to sell, but it might not suit every boat. The materials were very cheap, and the cost would depend upon the ability of whoever made it.

He thought if they gave it to a mechanic he might not make the right thing, but he would be sure to ask a big price until he discovered its simplicity.

With regard to the description given by Mr. Joseph Moore, it was quite accurate, but his machine was not intended for small river work. It was intended to be used on an enormous scale in estuaries or large harbours, where it could do a large amount of work with great rapidity and accuracy during a half tide.

With reference to what Mr. Allanson-Winn had said about working at the different depths, they generally had an idea before going out in the morning what depths they would be working at, and they could arrange the apparatus to suit. But there was no difficulty about arranging it to suit shallow or deep water according as they required it by making the machine on the telescope principal.

The ordinary commercial galvanised iron work and tubing answers. The triangular glass tubing can be made to any size, say with $\frac{1}{2}$-in. or $\frac{3}{4}$-in. diameter tubing, each side being from 36 to 40 or more inches in length. An ordinary country carpenter could sink the glass tubing in a wooden frame. [See Figs. 1 to 6 inclusive.]

On the most Economical Span for Long Girder Bridges with Numerous Spans of Equal Length.

By Bindon B. Stoney, LL.D., F.R.S., Ex-President.

When a girder bridge consists of numerous spans of equal length it may be proved that, theoretically, the most economical arrangement of the spans occurs when the cost of the main girders of one span equals that of one pier, assuming that the piers themselves are approximately of equal size and cost.

The quantity of material in similar girders, similarly loaded—that is, with the same load per running foot—varies theoretically as the squares of their lengths, and this is substantially true in practice for railway girders between 80 and 200 feet in length.*

Let it then be granted that the cost of the main girders of each span varies as the square of their length, and that the cost of each pier is practically constant, though the length of the span may vary slightly within moderate limits.

Let K = the cost of one pier.

l = the length of a standard span—*i.e.*, a span whose main girders cost the same as one pier.

From this the cost of one pier, and also the cost of the main girders of a standard span, per foot run of bridge, equals

$$\frac{K}{l} \qquad (1)$$

If, however, the span be increased somewhat, so that its

*Chapter X. Stoney on Theory of Stresses.

length becomes $l + x$, then the cost of one pier per foot run of bridge becomes

$$\frac{K}{l + x} \cdot \tag{2}$$

and the cost of the main girders of this longer span per foot run of bridge equals

$$\frac{K \frac{(l + x)^2}{l^2}}{l + x} = K \frac{l + x}{l^2} = \frac{K}{l} + \frac{Kx}{l^2} \tag{3}$$

Subtracting (2) from (1), the *saving in cost* of the pier per foot run of the bridge from the enlarged span equals

$$K \left(\frac{1}{l} - \frac{1}{l + x}\right) = K \left(\frac{l + x - l}{l^2 + lx}\right) = K \frac{x}{l^2 + lx} \tag{4}$$

Again subtracting (1) from (3), we find that the *increased cost* of the main girders of the enlarged span per foot run of bridge equals

$$K \frac{x}{l^2}; \tag{5}$$

but this latter quantity exceeds (4), and therefore the excess cost of the main girders of the enlarged spans is greater than the saving in the piers due to their being spaced further apart and being fewer in number.

In a similar manner it may be shown that reducing the length of each span is attended with a certain saving in cost of the main girders per foot run of the bridge, but this saving is not equal to the extra cost of the more numerous piers when thus placed closer together than the standard span.

Mr. Liddell, the Engineer of the Crumlin Viaduct, is said to have been the first to draw attention to this rule, and Professor Unwin, in his book on Wrought-iron Bridges and Roofs, gives a proof of the rule, but, as his proof involves the differential calculus, the average engineering student may find the foregoing proof somewhat simpler.

[5th April, 1905.]

MR. ROBERT COCHRANE, I.S.O., President, in the Chair.

The following candidates were balloted for and duly elected :—

Messrs. EDGAR ANDERSON and RAWDON GREENE, as Associate Members.

FURTHER ADVANCES IN THE STUDY AND TREATMENT OF SEWAGE.

By W. KAYE PARRY, M.Inst.C.E.

IN December, 1888, the writer read his first paper before the Institution of Civil Engineers of Ireland on the subject of the purification of sewage, and from that time to the present day he has followed closely the researches of those who have devoted themselves to the elucidation of this complex problem. In the year 1895 two papers were read before the Institution, one by Dr. Adeney and one by the writer, on the subject of recent advances in the study and treatment of sewage. Both these papers, whilst dealing in general terms with the researches of other chemists and engineers, were more particularly intended to describe the work done by the author and his colleague in a similar direction. The march of events has proceeded so rapidly since these papers were written that the contents may now almost be regarded as ancient history, although it may be claimed that the work which had been done and the results which were recorded contributed another chapter to the voluminous literature which this subject has produced. Looking back upon the statements which were then made, in the light of the most recent experience and research, the writer does not find it necessary to

retract or seriously to modify any of the conclusions which he arrived at at that time, but, even if recent developments in bacteriological research did render it necessary to reconsider his views, at all events he would be able to claim that in this respect he did not differ from any other engineers or chemists of the day. It is not necessary in addressing an audience of Civil Engineers to enter into details as regards the origin and growth of bacterial methods for the treatment of sewage which are so much in vogue at the present day. Some information on this subject can be gleaned from the previous papers already referred to, whilst the literature of the last ten years is so voluminous that it would be idle to attempt to epitomise it in a short paper before this Institution ; suffice it to say that it is now generally known and understood that the purification of sewage is entirely, or almost entirely, a biological question, and this, briefly stated, constitutes the great difference between the opinions which prevail at present and the principles which were generally accepted twenty years ago.

Members of this Institution who are in the habit of filing that excellent publication entitled *Engineering* will find in the issue for October 7th, 1892, an article headed "The Purification of Sewage of Microbes," in which it is pointed out that the fermentative changes which take place in sewage during the process of purification are due not so much to chemical changes as to the action of micro-organisms, and it may be fairly claimed for Ireland that some of the earliest attempts to effect sewage purification on a practical scale by utilising the action of these organisms were made by the writer, and were based upon the original researches of Dr. Adeney. The essential difference between the *modus operandi* adopted by Dr. Adeney and the methods of other chemists who have engaged in these researches was that Dr. Adeney always favoured the encouragement and development of the work of these organisms by feeding and nourishing them by

adding certain chemicals to the sewage, whereas all the more recent work has been done without the use of chemicals by merely providing suitable conditions for the growth and multiplication of the various organisms. It must be admitted that there are considerable disadvantages attendant upon the employment of chemicals for the development of the organisms in sewage treatment, but it must be equally evident to all those who have followed the subject closely that to establish and maintain the conditions necessary for the successful work of these organisms without the employment of chemicals is also beset with corresponding difficulties. Let us take, for example, the question of sewage sludge. The chemists, bacteriologists, and engineers in 1897 were convinced that biological methods of sewage treatment offered a complete solution of the sludge problem. It is only necessary to read the papers read on sewage disposal at the Conference of the Sanitary Institute at Leeds in 1897 to substantiate this statement. At that time it was claimed for the anaërobic organisms that they had the power of liquefying all the solids contained in the sewage, and that, given suitable conditions to enable them to accomplish their object, the result would be a complete disappearance of all the solids, and, in consequence, the final abolition of sewage sludge. In this connection it is very instructive to read the report of the Local Government Board enquiry at Exeter, which was held on November 24th, 1897. At this enquiry a large amount of scientific evidence was given in support of the septic tank system of sewage treatment. One of the witnesses, a very distinguished Fellow of the Institute of Chemists, stated that " the important fact which appealed to him in this bacteriological system was that the whole of the solid matters that went to make up the sludge, which was such a nuisance and great expense on all ordinary sewage works, was entirely demolished and destroyed by the microbic action. Instead of having a considerable quantity

of sludge they had nothing but a fine silt or grit, which could be removed without nuisance and without expense. That was the first great point, and it was an important point, that should be borne in mind in connection with the bacterial process, whether they were carried on by this process or by any other.'[1] Let us now see how far these statements have been substantiated when the methods which were then advocated were brought into practical use on a large scale. In an official report of the Rivers Department of the City of Manchester, dated July, 1902, and prepared by Dr. Gilbert J. Fowler and Mr. J. P. Wilkinson, the following statement is made as regards the work of the septic tank :—" With a tank equal to half the daily flow of Manchester sewage it is possible to digest about twenty-five per cent. of the total of the suspended matter in the sewage." From this it would appear that the practical work of the septic tank, instead of liquefying the whole of the solids, is only able to deal with twenty-five per cent. The subject of the treatment of Manchester sewage will be referred to again in this paper, but this one illustration is given to show that the hopes and anticipations of the distinguished chemist have been falsified in practice. It is yet to be seen whether the digestion of twenty-five per cent. of the solids is sufficient justification for the use of the septic tank, or whether it may not yet be proved that some simple and more efficient method of separating the solids from the liquid may not be discovered. At present, for want of something better, the septic tank or liquefying tank has come into general use as a preliminary to the treatment of the liquid on bacteria beds or continuous filters. When we turn from the first stage to the second stage of sewage purification we find that finality has not been reached in this direction either. A few years ago it was contended that the first stage of purification having been accomplished by the anaërobic organisms, all that was necessary was to afford opportunities to the aërobic

organisms to complete the work which their fellow-microbes had commenced. This, it was said, could be accomplished by discharging the effluent from the septic tanks into contact beds. These contact beds are familiar to members of this Institution, and need not here be described in detail; suffice it to say that each bed is allowed to fill with the liquid, to remain full for a longer or shorter period, and then to empty itself, and after that to stand empty or rest for another period, and then to be filled again. It has been usual to provide for not less than three and not more than four fillings to each bed in twenty-four hours. The idea was that whilst the bed was resting the organisms were freely exposed to the air, and that they were able to provide themselves with sufficient oxygen to enable them to deal successfully with the next dose of liquid; but a little consideration will show that this action can scarcely be described as a purely aërobic one, because during the time that the bed is standing full of liquid no air can reach the organisms which are growing on the surfaces of the filtering material of which the bed is composed. It must be assumed that if these organisms can only perform their functions when they are fully provided with the oxygen which they require, then there must be a very appreciable reduction in their activity towards the end of the time that the bed stands full. Simultaneously if, as we may reasonably assume, the anaërobic organisms are present in considerable numbers in the liquid itself, they may possibly become more active just in the same ratio that their aërobic brethren become less active, so that it would look as if the bacterial action in a contact bed was of a much more complex character than that which was originally claimed for it. Observations made of the actual working of contact beds have served to support these views, and it is now considered that to get the best results from a bed of this character it is necessary to limit the period during which the bed is allowed to stand full of liquid. These

and similar considerations have led many chemists and biologists to believe that the contact bed is not the best method of utilising the functions of aërobic organisms in sewage purification. It has been thought that if some method could be devised whereby these organisms would never be deprived of air they would accomplish their work very much more thoroughly, more expeditiously, and therefore more economically. These views have led to the production during the last two or three years of continuous filters instead of contact beds for sewage purification. On the whole, the use of these continuous filters has been attended with good results. The published figures show that the percentage of purification is usually somewhat higher in a continuous filter than in a contact bed of the same cubic capacity, but the difference is not as marked and the advantage gained is not as great as had been expected. Continuous filters in theory constitute a marked advance upon contact beds. In practice the use of these filters is beset with difficulties of its own, and has given rise to some fresh troubles which did not occur when contact was adopted instead of continuous filtration. The principal difficulty is, of course, the regular and even distribution of the liquid over the entire surface of the filtering material. The market is full of sewage distributors of all kinds and characters, several of which have worked reasonably well and given fairly good results, but those members who wish to realise the full extent and the nature of the difficulties attendant upon the uniform distribution of sewage on filters are recommended to read the two papers written respectively by Mr. J. E. Willcox, A.M.Inst.C.E., and Dr. George Reid at the Conference of the Royal Sanitary Institute in Glasgow last July.

There is another feature in connection with the continuous filters which has given some trouble—namely, the amount of suspended matter which comes over along with the filtrate.

It does not seem yet to be fully understood why the quantity of suspended matter in the liquid from a continuous filter should be so much greater than that which comes from a contact bed, but there is very little doubt that it is so. In the evidence which Col. Harding gave before the Sewage Commission, he stated that the effluent from the continuous filter which was tried at Leeds contained not less than 8.14 grains per gallon of suspended solids. It is obvious that an effluent of this character may require to be dealt with in some way before it can be discharged into a water-course, and if it becomes necessary to provide settling ponds or tanks this will introduce further complications, and tend to increase both the trouble and expense of purification.

Tank Capacity.

One feature of modern sewage works is the great increase in the tank capacity which has to be provided compared with the old days of precipitation by chemicals. In this connection some interesting figures will be found in a pamphlet published on sewage treatment and sludge disposal by Mr. Santo Crimp in 1893. In this pamphlet the late Mr. Santo Crimp gives the capacity of the precipitation tanks as compared with the daily flow of sewage in a number of towns as follows :— "Coventry, 42 per cent.; Birmingham, 56 per cent.; Burnley, 56 per cent.; Leicester, 40 per cent.; Wimbledon, 80 per cent.;" but he is careful to state that in the last case the works had been designed to allow for a large increase in the population. As most members of the Institution are aware, it is generally laid down by the authorities that the septic tanks, which are at present so much in use, should be capable of containing at least one and a half times the dry weather flow of the sewage of the district they are intended to deal with. In other words, that, whereas ten years ago the tank capacity did not exceed 50 per cent. of the daily flow, the

present tank capacity required is 150 per cent. This is a factor which is sometimes overlooked when making comparisons as to the former and the present cost of sewage treatment.

Contact Beds without Tanks.

Some early advocates of the bacterial treatment of sewage were so confident that the micro-organisms which the sewage contained were able to deal successfully with both the solid and the liquid impurities that they deprecated the construction of any preliminary tanks for liquefaction or sedimentation. Mr. Dibdin was the principal exponent of these views, and he designed several works on these principles. The writer has before him an account of the sewage disposal works for Hampton, which were carried out as recently as 1898, and which he has had the opportunity of inspecting on several occasions. These works, which are of a very costly character, include a series of three contact beds; the sewage is passed direct from the sewers into the first beds, and thence, after resting in the usual manner, it is allowed to flow into the second beds, and finally into the third beds, and the effluent from the lowest beds is eventually lifted and delivered on to the land or into the river. In the pamphlet it is stated that the great advantage of this system of sewage purification was that no sludge remained after the sewage was purified, as all the organic matter in the sewage was converted into inoccuous organic substances that are soluble in the effluent. It is further stated that "by Mr. Dibdin's method of treatment the sludge bugbear is annihilated by the myriads of micro-organisms present in the sewage and existing under favourable conditions provided by the construction and careful working of the beds." The pamphlet also states that the treatment, as a whole, was a marked success. Five or six years' work, however, demonstrated that the sewage could not be successfully treated by these contact beds. The

greatest possible difficulty was experienced, owing to constant sludging up of the contact beds, and but for the ingenuity of the works' manager in devising a rough and ready method for intercepting the sludge on the surface of the beds before it had time to choke them up the installation would have been at a stand-still long ago. As a matter of fact, so far from the sludge difficulty having been overcome, a number of men were constantly employed in removing the accumulations of sludge from the surface of the beds. Owing to the great trouble which was experienced, the sanitary authorities have recently constructed a new form of liquefying tank, which has just been completed, and which is, at the present time, in operation. This tank is designated the hydrolytic tank, and it possesses many features of interest. The author was afforded an opportunity of personally examining this tank after it was completed and before it was brought into use. The tank has been designed by Mr. Edwin Ault, C.E., in conjunction with Dr. Owen Travis. Its conception is the result of a close study of the numerous experiments recently conducted by the State Board of Health of Massachusetts. The main feature in this tank is its division into chambers so devised as to facilitate liquefaction and to afford opportunities for drawing off the sludge without interfering with the work of the tank. It is understood that the authors of this system intend, when the proper time comes, to publish full particulars and to give the results which have been achieved, and the writer is not at liberty at present to disclose any particulars which have been furnished to him. The principal reason for mentioning this new departure in this paper is not only because of its interest as an apparently successful attempt to improve the construction of the ordinary liquefying tank, but also as an illustration of how completely the hopes and anticipations of the chemists and engineers who designed the Hampton works in 1898 have been falsified in the comparatively short

time which has elapsed since the works were put into operation. The Council is now once more face to face with the old bugbear of sewage sludge, which neither the septic tank nor the contact bed has been able to overcome. The sludge from the hydrolytic tank is drawn off periodically, and has to be dealt with either by being dug into the ground or carted away. These failures must have been a bitter disappointment to the enthusiasts who, a few years ago, pledged their reputation in stating that the sludge difficulty had been finally and successfully overcome.

Foreshore Pollution.

No paper on sewage purification written at the present time would be complete without some reference to the very interesting work which has recently been carried out by Professor Letts, of Belfast, on the subject of the pollution of the shores of Belfast Lough consequent upon the discharge of the untreated sewage from the city into the estuary. As many members of the Institution are aware, this trouble has taken the form of a great and excessive growth of a particular class of seaweed, which owes its origin to the sewage-polluted water. A full account of this seaweed will be found in the two reports which Professor Letts has published. The weed is known as the *ulva latissima*, and Professor Letts has shown that the growth of this weed is encouraged very largely by the nitrates which are present in the liquid. The problem, therefore, of the successful treatment of Belfast sewage presents exceptional difficulties, because hitherto it has been one of the aims and objects of the chemist and engineer to produce an effluent in which nitrates are present. They have always been regarded as one of the evidences of completed purification, whereas it would appear that if the effluent from the Belfast sewage happened to contain any appreciable quantity of nitrates the growth of the *ulva latissima* would

be still encouraged and the purification of the foreshore would not be completely accomplished, even although a very complete oxidation of the organic substances in the sewage had been effected. Dr. Letts carried out a very large number of most interesting experiments on sewage purification by means of a septic tank and contact beds, and the analyses are tabulated in his second report. The results as a whole were encouraging but for the fact that in many cases the effluents contained some nitrogen in the form of nitrates, and in some instances the quantity found amounted to .19 parts per 100,000, whilst the average amount from the lower contact beds was .56 parts per 100,000. There are many other interesting facts in these reports, but it is impossible to give all the particulars in this paper ; amongst other points we may mention the investigations as regards the changes in the free and albuminoid ammonia on keeping the septic tank effluent. But there is one part of the report which must not be passed over in silence, and that is the work which was done in connection with the question of the reduction of nitrates by sewage. Professor Letts published two coloured diagrams, which the writer has reproduced. The first of these diagrams illustrates the effects of treatment in contact beds only, and the second gives the effects of treatment in contact beds preceded by the septic tank. In the first diagram it will be observed that in the sewage the nitrogen occurred in the form of nitrates 4.43 per cent. ; free ammonia, 67.41 per cent. ; and albuminoid ammonia, 28.16 per cent. It will be noticed that in the effluent obtained by contact beds only the nitrates amounted to .95 per cent. ; the free nitrogen to 57.91 per cent. ; the free ammonia to 32.91 per cent. ; and the albuminoid ammonia to 8.23 per cent. Now, if we turn to the second diagram and compare the constituents of the effluent, we notice a large increase in the percentage of nitrates, a small increase in the percentage of free nitrogen, a large decrease in

the percentage of free ammonia, and a small increase in the percentage of albuminoid ammonia. Professor Letts points out that although the reduction in the quantity of albuminoid ammonia in the effluent compared with the quantity in the sewage would tend to discourage the growth of the *ulva latissima*, the increase in the percentage of nitrates as compared with the sewage would rather tend to encourage its growth. For this reason he is of opinion that in treating the Belfast sewage some special steps should be taken to reduce the nitrate in the effluent in order to ensure the disappearance of this weed from the shores of the lough. Foreshore pollution, in the case of other estuaries, does not always take the same form as it does in Belfast. Very frequently the trouble that arises is mainly created by the mud banks which are formed by the discharge of the suspended matter in the sewage into the sea. The writer had the opportunity of going somewhat closely into this question, in conjunction with Dr. Adeney, in connection with the question of the effect of the discharge of the Rathmines and Pembroke sewage into the tidal estuary of the Liffey. Full particulars of these researches will be found in a joint paper read before the Institution of Civil Engineers of England on 12th November, 1901. As the result of their investigations the authors came to the following conclusions :—That to discharge any sewage into a tidal estuary without creating a nuisance the following conditions should be complied with :—

1. The discharge should be made into a definite deep-water channel with a current setting seaward.

2. The width of the water in the deep channel at low tides must be sufficient for the adequate dilution of the sewage.

3. The whole of the sewage should reach open water before the turn of the tide.

4. The heavy solids and the floating matter should be separated from the sewage before its discharge.

5. The dilution of the sewage with subsoil or surface water prior to its discharge is distinctly advantageous, as it tends to encourage purification by promoting healthy bacterial action.

In the discussion upon this paper it was made very clear that there were very few tidal estuaries in the Kingdom in which all these conditions could be successfully complied with, and it was evident that the absence of foreshore pollution in the estuary of the Liffey was partly due to the very favourable conditions which obtain there as compared with other outfalls of a similar character.

The best form of Tank.

In an earlier part of this paper allusion has been made to the recent attempt to improve the septic tank by altering its form. The writer desires to place on record his impression that engineers have still much to learn regarding the best and most economical design for the construction of sewage tanks, whether for liquefaction, sedimentation, or chemical precipitation. The percentage of suspended matter which can be arrested in a tank depends to a very large extent upon the form of the tank and the arrangements which are made for the admission and discharge of the liquid from it. It is now fifteen years ago since the writer constructed his first Dortmund tank at Dundrum, and the results which were obtained there clearly demonstrated the value of a tank of this type for facilitating the separation of the suspended matter as compared with the septic tanks or liquefying tanks now in general use. Little or no attempt is made to encourage sedimentation by gravitation in the septic tanks, whereas the writer has no doubt whatever that a great deal of the trouble in contact beds is entirely due to the fact that a large amount of suspended matter, which might be arrested in the septic tanks if they were properly constructed, is permitted, owing

the Sanitary Institute at Leeds in 1897, at a time when all the enthusiastic bacteriologists were trumpeting forth the statement that the old things had passed away, that they were to have a new heaven and a new earth, and that there was to be no more sludge. His words were as follow :—" The writer confesses himself unable to endorse this opinion; he does not believe that with average town sewage it is possible to have sewage works without sewage sludge. Of course it may be possible to reduce the quantity of sludge to a minimum, but the day is far distant when it will disappear altogether."

Dr. Fowler's observations on the capacity of the contact beds, on automatic gear, on the composition of the filtrate, and on the cost of the operations are all most instructive, and it is impossible to do justice to them by short quotations. Allusion must, however, be made to a most interesting table which he publishes showing the comparative data regarding the filtration of tank effluents as carried out at Manchester, Accrington, Burnley, Oldham, and Birmingham. Dr. Fowler is a firm supporter of the contact bed as compared with the continuous filter, and, whilst it is impossible to accept all the conclusions at the end of his paper in the general terms in which they are formulated, nevertheless his vast experience and the excellent work he has done at Manchester render it imperative to respect and give due weight to the opinions which he expresses.

The Sewage Commission

It is quite impossible to close this paper without referring to the work which is being done by the Royal Commission on sewage disposal which has now entered upon its seventh year. This Commission was appointed on 7th May, 1898. It has examined a large number of witnesses; the members have visited many sewage works throughout the country, and they have instituted, through their own offices, a large number of

original scientific investigations. Several reports have been issued already, but much remains to be done, and it will be probably some years before they are in a position to issue their final report and to conclude their labours. Any attempt to deal with these reports in a short paper would be futile and utterly misleading. The exponents of various rival systems of sewage purification are attempting to make capital out of these reports by republishing quotations from the evidences of the witnesses which appear to be favourable towards the particular methods of sewage purification in which they are interested. A great deal of the evidence itself is so contradictory that it is possible to draw any number of different conclusions, according to the personal predilections or prejudices of the critic. Suffice it here to say that the work of the Commission, at all events, has proved that sewage can be successfully purified without land treatment, and, as a result, the Local Government Board of England is beginning to relax its rule and to permit the discharge of a properly purified effluent into an estuary or river without insisting upon land treatment in every case. The burden which has been imposed upon large urban communities by the cast-iron rules of the Local Government Board regarding land treatment as a supplement to any form of sewage purification has become almost intolerable. Many large cities were both able and willing to erect suitable purification works in order to protect their rivers from pollution, provided they had been allowed to discharge the effluent direct from the works into the river, but they were not always either able or willing to purchase large tracts of land in order to carry out this supplementary treatment. Had this rule been relaxed ten or fifteen years ago a vast amount of river pollution would have been saved and great economies would have been effected in the rates. In thickly populated counties like Lancashire and Yorkshire it is almost impossible to purchase land for sewage treatment,

except at a prohibitive price, so that many towns have been unable to carry out any works at all because they could not obtain the sanction of the Local Government Board without buying a considerable area of land, and this land could not be obtained at anything like a reasonable price.

It may be of some interest to the members to conlcude this paper by showing some lantern slides illustrating a few installations for the bacterial treatment of sewage which have been recently designed and carried out by the author and his partner.

The largest of these works are those at Armagh, which provide for a population of eight thousand persons, and which have been in operation for two years, and the smallest is a simple little plant for dealing with the sewage of a country house, not far from Dublin, which is now in course of erection.

[3rd May, 1905.]

MR. ROBERT COCHRANE, I.S.O., President, in the Chair.

The following candidates were balloted for and duly elected:—

DAVID EDWARD BURTCHALL, as a Member.

THOMAS J. BIGGS, as an Associate.

SOME NOTES ON BACTERIAL PURIFICATION.

By J. G. L. HAYES, A.M.

IT is questionable how far anyone unacquainted, like the writer, with bacteriology as a science, is justified in discussing bacterial purification. The subject, however, possesses two very distinct sides—the biological and the engineering. It is from the latter standpoint that we propose to view it.

It would seem necessary to urge engineers in this country to give these things some attention. There is no escape from the conviction that many lives are needlessly lost every year, and many more people have their constitutions weakened because the principles of bacteriological purification, both of water and sewage, are imperfectly understood. Fortunately there is no longer any need to fight the battle of the microbe, as Dr. Thudichum said two years ago, but there does appear to be a great need of drawing attention to the fact that this is a vital question, and that it, therefore, demands earnest consideration.

Let us look first at the water question, and subsequently turn to the sewage problem.

The Purification of Water.

It is the writer's belief that the typhoid case-rate of a town varies inversely as the hygienic purity of its water supply. This proposition has long been propounded, but such is the responsibility which its acceptance lays upon the medical and engineering professions that it is no surprise to find the theory not universally accepted. It is not affirmed that water is the only means of conveyance for the typhoid bacillus, but that it forms the principal one. Hence, if your typhoid rate is high the quality of your town water will be found to be relatively low, and *vice versâ*, for, while it may well be disputed as to whether some diseases are communicable through the water supply, cholera and typhoid are so beyond cavil.

Investigations have been made in England to ascertain as far as it was possible at the time the relation that existed between typhoid fever and the water. Some of the results are given on the chart (Fig. 1), and are sufficiently startling. It is seen that the case-rate is highest in those towns supplied from upland mountain sources and from deep wells, and lowest in those which draw their supply from rivers. This is speaking broadly, for some towns, like London, have several sources.

I wish to draw your attention to what, in my belief, is the reason for this. The reason is that towns depending upon rivers for their supply have for many years admitted the necessity of careful filtration, while those drawing their water from the other sources mentioned rely upon its natural purity, and will not, as a rule, condescend to give the filter a second thought. If we make a more detailed inquiry we find this conclusion to be

amply verified. Thus, it is not strictly correct as above intimated, and it is somewhat disadvantageous, to class London with towns drinking filtered river water, because out of the eight water companies (now merged into the Metropolitan Water Board) only three supply filtered Thames water alone; one company supplies unfiltered well water alone, the others mixing the waters, and *the districts supplied with filtered Thames water have a lower typhoid case-rate than the rest of London.* Then you will notice the improvement effected by proper filtration in the case of Worcester There is a drop from 110 cases per 100,000 inhabitants in 1894 to 36 in 1895, the cause of which was that in 1894 the number of filters was largely increased, and a general effort made to improve the quality of the water. Exeter furnishes us with another example. This city had an enteric case-rate of 70, but in 1901 the filtering area was doubled, and in a few months, when the beds were matured, the number of cases fell to 15.

The 200 largest towns in England have been classified according to their sources of water. Here are their average annual typhoid case-rates:—Towns deriving their supply from wells sunk in the red sandstone, 117; those supplied from wells in the chalk, 109; from upland sources, 119; from mixed sources, 91; from rivers, 82. Almost invariably it is found that towns supplied with unfiltered water, from whatever source, have a higher typhoid rate than those supplied with filtered water, a result that might have been foretold, the rate varying inversely as the purity of the supply. The exceptions to this rule, and there are very few, are probably due to the faulty design and bad management of the filters.

In the face of this fact that unfiltered upland water supplies are accompanied by the highest typhoid case-

rate, we find this expensive source the favourite one in Irish practice. I believe the truth of the matter is that many engineers have little faith in sand filtration, and do not realise its value. Some engineers are also afraid of pumping, although pumping schemes are usually lower in capital cost, and so they will often leave an eminently suitable and comparatively cheap lake or river source untouched, to go farther and fare worse. The practice of English engineers tend towards the filtering of these mountain waters, When visiting the new Birmingham works at Northfield on several occasions, I have been struck with the adequate provision for filtration that the eminent engineer of those works has deemed necessary. A passing allusion to this great scheme may be of interest. Eighteen filter beds, having a combined area of 14 acres, have been constructed, and there is space for as many more. The service reservoir is semi-circular in plan, and holds 200 million gallons, the straight wall being nearly one-third of a mile long. A decided reduction in the enteric case-rate of Birmingham, at present somewhat high, may be expected when the Welsh water comes fully into use.

It is not my present purpose to attempt to prove conclusively the relation of typhoid to the water supply, as such a subject would demand a whole paper to itself, but I have endeavoured to show that such a relation exists. It is my firm conviction that efficient biological filtration is an effectual preventative of four-fifths of the cases of enteric in our towns.

The question then arises—What is efficient bacterial purification? The writer would answer that it is the result of properly designed and intelligently managed biological sand filters. Let us consider some of the main points of an efficient installation.

1. Proper Construction.

In dealing with the action of a sand filter it is important to bear in mind that the sand is not the filtering medium, but is merely the nucleus on which the filtering material is formed or deposited. This material consists of mud and masses of micro-organisms. Hence, a coarse sand is probably better than a very fine one, because no sand is fine enough to obstruct the passage of the bacteria, and the former does not need skimming so frequently, while forming an equally good base for the deposition of the actual filtering medium.

An efficient system of effluent drains is of the first importance, so as to ensure that every part of the filtering material does its share of the work. This result is obtained by a sufficient thickness of graded gravel over the drains. A very good arrangement is for the effluent pipe from each filter to be turned up in the filtered water tank, terminating with a bell mouth at the same level as the surface of the sand, so that the depth of water over the sand is also the filtering head.

It is of great importance to have a gauge automatically recording, and, if possible, regulating, the filtering speed. There are some on the market, but it is not difficult to design one for special cases, actuated by a float.

Ventilators or aeration pipes are a very doubtful advantage. They act much more frequently as inlets than as outlets, and when the filtered water in the tank rises I have known the air to be forced out through the sand, causing holes, rather than pass through the air pipes. They are of no use when a bed is first filled, because there is then no "surface" to be disturbed, and when a bed is matured it should never be emptied until it is clogged.

Of course, it is understood that the outlet of a filter should always be sealed by the water in the effluent tank. There should be ample spare filtering area, standing by for occasional use.

2. Management of Filters.

It is most advisable for the effluent to be run to waste until a bed is in condition, both when it is first filled and after skimming. It is not mature until a proper surface, consisting of mud and algæ, has formed on the surface of the sand. This usually takes from one to four weeks, according to the turbidity of the unfiltered water, unless a coagulant is used, which practice is now very fashionable in America. The surface is less likely to be disturbed if the filtering speed is controlled by the outlet rather than the inlet until maturity is reached.

At Manchester last month some one said that the most effective filtering speed was 4 inches vertical per hour. He omitted to state that he referred to the water of his own works. It is most irrational to make such a statement as this, because, obviously, the rate will depend upon the quality of the unfiltered water. The rate of filtration in the case of water at all contaminated by organic matter should certainly not exceed 300 gallons per square yard in 24 hours, or about 2.7 inches per hour. To be perfectly safe, and to remove, say, 99.7 per cent. of the bacteria, not more than 200 gallons is advisable, equivalent to a filtering speed of rather less than 2 inches of depth per hour, or, at the outside, a million gallons per acre per day. A common error is to run the beds too fast, and then say that sand filtration is useless. The great importance of a low filtering speed is seen from the following fact:—*The number of bacteria in the effluent*

will increase in a greater ratio than the accelerated rate of filtration, especially in the case of a ripe bed, which is, perhaps, doing excellent work. At the low rate a slight increase will have the effect of washing down into the effluent drain a large number of the organisms arrested on the particles of sand.

The depth of water over the sand should not, in my opinion, be more than two feet, nor less than about one foot. If it is too great, as is well known, the sand gets compressed and even fissured, when masses of arrested algæ are forced into the effluent.

We should not enter into these elementary facts, but that the methods pursued in at least one of Ireland's largest towns point to the need of doing so.

When the filter becomes clogged, about three-quarters of an inch should be skimmed off the surface and wheeled to the washer, the bed then being refilled with water. This should be repeated each time the bed clogs until about six inches have been removed, a like extra depth of sand having been given at the first filling, when six inches of clean sand should be spread. It is important to remember that the object of washing sand is not to remove all its micro-organisms, but to get rid of some of the mud so as to allow the water to percolate more freely. Sterilised sand appears to have no filtering abilities, and would require many months to get into condition. A mechanical sand washer, that will clean the sand sufficiently and rapidly, is a good investment. Greenway's patent is the best I know, and is economical, a £300 machine worked by water washing 15 cubic yards in six hours, with one man feeding it. (I am speaking from memory; we had two of them at the Worcester water works.) The invention has yielded nothing to the patentee, who is a waterworks engineer, yet the late Mr.

Thomas Hawksley said the inventor of this machine should be driving his carriage and pair.*

3. Analysis.

Regular and frequent bacteriological examinations, both of crude and filtered water, should be taken. No filter should be constructed without facilities being provided for taking the samples of the effluent from each individual bed. This can be accomplished either by keeping each effluent pipe separate, terminating in the tank above the usual water level, or a pipe may be carried down through the filtering material into the main effluent channel. The sample bottle is lowered down this by means of a simple contrivance, which also fixes the stopper before the bottle is withdrawn. With this arrangement a typhoid epidemic was recently prevented by tracing the germs to a faulty filter, and cutting it out.

The Americans term the foregoing "slow" sand filters, and use high-speed pressure filters a great deal. Having had no experience with them myself, I should be glad of information on the subject, particularly as to whether they can be trusted to run without attendance.

The Copper Sulphate Treatment.

There is one other point connected with water purification I should like to bring before you, and that is the use of copper sulphate as a germicide. The United States Department of Agriculture carried out numerous

*Since writing the above Mr. Stewart Caink has designed a sand and gravel washer of a most comprehensive and economical kind. The machine he has built lifts the material 50 feet vertically, washes it and sorts it into 3 or 4 grades from sand to large pebbles, the largest pieces gravitating to a stonebreaker. It is all worked by one engine, at present a portable steam, but a 36 h.-p. electric motor is being installed. Since it was put on the machine has saved £60 a week in wages.

experiments with this chemical, and it is now used in America, not only for destroying the green algæ and other confervoid growths in filtered water tanks and reservoirs, but also for exterminating typhoid and other diseases. It would appear that copper has exercised a beneficient germ-killing power from the time the Chaldeans first formed those wonderful pots and bowls one sees in the British Museum. Dr. George T. Moore, of Washington, found that if water strongly infected with typhoid germs were left in a clean copper vessel at room temperature for eight hours, it became sterilised; and the Health Board of New York has reported that while gold and silver coins and paper money literally swarm with germs, not a single one has been found upon a copper coin. These are most important conclusions. Turning to water purification, it has been found that 1 part of copper sulphate to 50,000,000 parts of water in a reservoir will destroy the algæ, but the dose is increased in some cases up to 1 in a million. Even then the cost is very little—about half-a-crown per million gallons If water should be strongly charged with cholera or typhoid germs one part of the sulphate to 100,000 of water will quite exterminate the disease. A short article appeared in "*Water*" (the only British journal, so far as I know, for water engineers exclusively) describing how the copper treatment removed a "fishy" taste from the water of Hanover, New Brunswick. There were 500 bacilli per c.c. in the water of the reservoir before the treatment, giving rise to a most unpleasant odour, but a dose of 1 to 4,000,000 reduced the number of organisms in 60 hours to nil, and completely sweetened the supply without even killing the fish with which the lake was stocked.

Drs. Rideal and Baines presented a paper on this subject last July at the Glasgow Sanitary Congress, dealing

with experiments they had carried out in the same direction. They verified the American investigations, and found that copper chloride was an even more active salt in the destruction of pathogenic organisms than the sulphate. No interest, however, has been aroused. There always seems a terrible amount of inertia to be overcome in attempting to introduce a new idea on this side of the "ferry."

The Purification of Sewage.

There have been so many papers read in England on the bacterial treatment of sewage in the last few years (though there were fewer in 1904 than in the preceding year or two) that you may reasonably wonder why the subject is again presented. One reason was given at the very outset, that we have hardly kept abreast of the times in this country, and need an occasional reminder to bring us up to date. Then I do not know of anything on the subject produced in Ireland recently, save the Delegates' Report on the Manchester Sanitary Congress in 1902. Again, papers on the sewage problem have invariably promoted a healthy discussion, which in itself is an unmixed good, and in the present case it will certainly be the most important part of the evening's deliberations. The writer feels very strongly that, be it by only Carlyle's "pitifullest infinitesimal fraction," we should surely do whatever in us lies for the benefit of our profession, the advancement of learning, and the good of mankind.

There are two more or less distinct schools of thought interesting themselves in the bacterial treatment of sewage. The one school, possessing the more liberal views, advocates the percolation or sprinkler system of aerobic filters, the other, on "good old Tory" principles, still adheres to the contact bed. A recent writer depre-

cated this division of sanitarians into opposite camps, failing to see that with humanity, as it is at present constituted, progress becomes possible on these lines alone; it is only through the disagreement of the inquiring that the unanimity of the wise can be attained. Possibly, however, this writer was not a party politician.

Just now the star of the aerobic system is decidedly in the ascendant, the success of its operations becoming widely known. But eight years ago three or four of us were crying in the wilderness, vainly endeavouring to persuade engineers to take it up. It is questionable whether there was another engineer besides my own master, in the days of my pupilage, who realised the correctness of the principles of aerobic filtration. It was almost amusing to find men even last year solemnly giving birth to ideas which were already seven years old. One engineer at the Glasgow Congress made the assertion that the whole point of sewage disposal was "distribution." When I told him this in 1898 he refused to believe it. In this paper, which was read at the Congress, he described a "patent" distributor he had "invented." Six years previously I had shown him the drawings of a similar machine, the specification of which amply covered his device. A communication on the subject of distribution of bacteria beds was not considered by the editor of the *Surveyor* of sufficient importance to appear in his columns in 1897. Some engineers, indeed, admitted the merits of the system when it was laid before them, but none took it up. Inertia enough.

As the history of the origin and rise of what is now termed the "sprinkler" system has not been published hitherto, it may be of interest to trace it here. The city engineers of Worcester (England) and Worcester (Massachusetts) have been for many years in correspondence.

Thus, the investigations into bacterial filtration of the Board of Health of that State—which, it is well known, began in 1887—quickly found their way to the "Faithful City." The engineer of this English city, by the way (Mr. Thomas Caink, A.M. Inst. C.E.), from about 1890 carried on investigations, assisted by his sons, in the biological purification of water.

Mr. Lowcock, of Birmingham, informs me that he first put down continuous aerated bacterial filters in 1891, and at the same time Colonel Waring, in America, was making experiments on somewhat the same lines. Mr. Lowcock's paper at the Institution of Civil Engineers in 1894, describing his experiments at Malvern, was a standard work, and is most instructive to-day. The Telford gold medal and premium was awarded for it. Prior to 1897 Mr. Scott Moncrieff had also been experimenting with bacteria beds, and Mr. Dibdin had commenced his classical investigations. On November 8th of that year, Mr. Caink, of Worcester, addressed Mr. Dibdin on the subject. As I was concluding my articles under Mr. Caink at the time, he has been good enough to permit me to reproduce part of the correspondence. It is as follows:—

"For several years I have followed with the greatest interest the investigations which have been carried on by yourself and other eminent chemists and bacteriologists relating to the purification of sewage by biological processes, and am particularly gratified to find at length what I had long been convinced of, that the entire sewage problem could be satisfactorily solved by artificial filtration.

"The conditions requisite for the successful treatment having been laid down by the bacteriologist, I apprehend it to be the function and duty of the engineer to

show how those conditions can be attained at a minimum of cost.

"I recently prepared a scheme entirely on these lines for the City Council here, but they have resolved on the adoption of a chemical precipitation scheme designed by Messrs. Beesley, of Westminster." I may say at once that after wasting some thousands of pounds the City Council returned penitent to their own engineer, and threw over Messrs. Beesley's scheme. We shall deal with Mr. Caink's scheme a little later. His letter continued:—

"In designing my filters for the scheme I have alluded to, I sought to provide in a maximum degree the conditions which you have pointed out as essential to the efficient purification of the sewage by filtration, the maximum amount of aeration at the least cost being the most important conditions. In working out the arrangement I experienced the greatest difficulty in providing what, to my mind, was a satisfactory method of distributing the sewage on to the surface of the filter. . . . It seemed better, too, that the water should fall on to the filter in the form of rain, by which air would be carried down to some extent with the liquid. Further, that discharging it in fine drops at frequent intervals, producing alterations of wet and dry—*i.e.*, of sewage and air—would accelerate the process.

"These and other considerations have led me to devise a form of distributor shown upon the accompanying drawings. It is in principle a Barker's Mill, driven by the reaction of the liquid flowing from it. The arrangement is simple, and provides for all the conditions mentioned above as necessary for an effectual distribution of the sewage, so as to give every part of the filtering material its proper share of the work to be done. It is capable of being applied to any of the usual forms of

filters, rectangular, oval, or circular. For the rectangular form I provide reversing valves, which automatically reverse the direction of the distributor each time it reaches the end of the filter, and causing it to traverse and re-traverse the bed. The oval and circular forms, however, are simpler, requiring no reversing valves." From all of which it will be seen that the writer (Mr. Caink) had at an early date grasped the main principles upon which the successful treatment of sewage depend. The earliest form of the distributor was the rectangular, fed by siphons from side channels. The next stage in its evolution was a one-arm rotary machine (Figs. 2 and 3), designed for a half-acre filter bed, and having a siphon chamber at outlet of effluent drain governing the discharge.* At this stage you see it was really a contact bed, sprinkler-fed, but the continuous aerobic principles were soon evolved, for in the 1897 Patent Specification Mr. Caink stated:—"The object of the invention which forms the subject of this application for letters patent is to so discharge the liquid on to the surface of the filter that the whole of the material shall be utilised by contact with the liquid, and at the same time in drawing air down with the liquid into the body of the filter, and further to render unnecessary the accumulation of liquid in the filter whereby for the time being the air is excluded." The first deliberate thrust is here made at the contact system, and time has, I think, amply verified Mr. Caink's advanced views.

There was something in what Sydney Smith said, writing to the *Edinburgh Review* a century ago, that—"He is not the discoverer of any art who first says the thing, but he who says it so long, and so loud, and so clearly,

*The figures do not show the *original* one arm machine, but that now being installed at Worcester.

that he compels mankind to hear him." In the present case the palm of absolute priority in the invention of the sprinkler does not rest in the hand of any civil engineer, inasmuch as Mr. Frank P. Candy, the sanitary engineer of Westminster, had protected a rotary machine worked on the "turn-the-handle" principle as far back as 1894. I believe Mr. Candy subsequently brought out an automatic apparatus more like our own, but at any rate a treaty was entered into with Mr. Caink, and the invention was henceforth known as the "Candy-Caink" Patent. There is no doubt that the Candy machines are the best in the market to-day. They were the first sprinklers of any kind, and the whole batch of these trumped-up so-called patents are clear infringements. If there is any patent at all in the harnessing of the natural forces for a particular purpose, there is none whatever in the incomparable apparatus of Messrs. Lather & Flat, A. Damseye Drawlicks, Ltd., and Ram, Shaker & Co., or any of the manufacturers who have pirated the device. As a matter of fact, proceedings have already been taken against one firm. What I do object to on principle is that the men who have the brains to invent a thing rarely get any pecuniary reward, and indeed often lose money over it, while smart business men, with small intellectual assets and an original code of morals, greedily seize all such things, and turn them with the power of Midas into gold. It is some comfort to find that they do not always escape the subsequent fate of Midas.

I understand that the present patent law is to be entirely revised, and all the great men in London are setting about the task. May they receive unbounded help and wisdom, for they sorely need it.

One of the foremost to recognise the efficiency of the

Candy-Caink system was Mr. H. C. Werner, an eminent German engineer. This gentleman had the distinction of introducing aerobic sewage purification into his country in 1901, for he designed the scheme for the town of Ems, which we are about to consider, the writer being his chief assistant. Though relatively small, this scheme is valuable as a type, for with one exception every detail of the treatment is the same in principle as that of the Worcester scheme of 1897. Bad Ems is a beautiful health resort on the banks of the Lahn. It is blessed with an enlightened municipality, and has always been in the vanguard of sanitary reform. The late Emperor used to stay here, and was on a visit to the town when he declared war against France in 1870. The population is 15,000 The town has the separate system throughout; the sewage is purely domestic, and has all to be pumped at the works. There are two complete sets of primary and secondary tanks and filters. The object was to provide in the most economical manner for the summer population, which is increased by visitors to double that of the winter. In adopting circular and segmental forms in plan, it was thought the most rational course was being followed; division walls were not put in where unnecessary, and armored concrete was the material used throughout. As to the use of this material (if you will pardon a digression) I must say it is very effective when suitably applied, and when the re-inforcing is the result of careful calculation. Mr. Werner being engineer to the Armored Concrete Construction Co., of Westminster, and a great mathematician, we had every facility for using it. Armocrete shows up best on heavy works, large fireproof buildings, bridges, harbour works, and so forth; it is costly for small jobs. We are all behind the Continent in the use of it.

But to return to the Ems scheme. The rising main discharges into a small circular chamber, the function of which is to form a species of buffer between the column of water from the pumps and the detritus tank. The inlet arrangements are the same as in the four inoculating tanks. They consist of a horizontal iron pipe leading to a vertical tube of armocrete, square in section, reaching to nearly the bottom of the tank. These inlets are found to assist the deposition of solid matter after the first filling. The detritus tank is a "Dortmund," in so far that its bottom is conical. It is fitted with an apparatus invented by Mr. Candy for removing deposit. The inoculating tanks are also fitted with the same appliance. The outlet of all these tanks is at the top on a peripheral weir, so that the liquid travels twice the depth of the tank. With the primary inoculating tanks the duplicate system commences, there being two complete sets, each consisting of two inoculating tanks, and four filters with channels and penstocks, so arranged that any tank may work with any of the filters; that is to say, either complete set of "machinery" may be used, or both sets, or if desired, any combination of the two. The tanks have a capacity of six hours' flow, which, with the time spent by the sewage in the intercepting sewers and pump-well, is sufficient for the decomposition of the organic solids. Before entering the filters, the liquid passes through shallow gauging chambers, in the floor of which is the upper leg of the inverted siphon feeding the Candy-Caink distributors. The filters are 52 feet in diameter, the thickness of material is 3 feet 6 inches, the primary and secondary beds having the same depth; the latter are provided with a 6-inch layer of polarite. There are suitable arrangements for dealing with the sludge from tanks, also for the minute quantity of "burnt-out ash"

or fine mineral matter, which is almost the only remaining impurity in the effluent from the secondary filters. The cost of these works was £5,000.

The Chester Scheme.

Major Tulloch has adopted the foregoing principles, with one notable exception, in the design of his Chester scheme. In the above description of the Ems works I purposely omitted any reference to the secondary inoculating tanks. This is the one point on which Mr. Werner differs from the rest of us, his system being "decomposition—aeration—decomposition—aeration." It is, of course, the third phase which is heretical, from the standpoint of aerobic doctrine, as this is the order of procedure in a contact bed, though in other respects the two are quite dissimilar. Major Tulloch discussed this question with me at the time, pointing out that in the Chester scheme it was "decomposition—aeration—aeration," in strict accordance with aerobic orthodoxy. The veteran engineer did not think it was advisable to reverse the process in mid-stream, but he used to say that he was glad Mr. Werner was trying it, and would be interested in the result.

We might notice in passing, that Major Tulloch completely fulfils all the conditions Mr. Caink laid down in 1897, the Chester and Worcester schemes being almost identical in their main principles. Also, that Mr. Lowcock, one of the oldest investigators, now writes that he has entirely adopted continuously aerated sprinkling filters—precisely our system, and the one which has produced such unparalleled results as 90 per cent. purification, at the rate of 2,000,000 gallons per acre per day, at Accrington, Birmington, York, and other places.

Before dismissing the Chester scheme, a brief reference

to Major Tulloch's report of October, 1901, will be instructive. It reads:—"Practically, the area of contact beds, according to the Local Government Board regulations, must be about *ten times as great*" (the italics are the Major's) "as that of the aerobic filters approved by tions, must be about *ten times as great*" (the italics are tanks of less than half the capacity which they required for a contact bed scheme The report continues:—"For some time past it has been known to bacteriologists that the effluent from contact beds, however satisfactory it may be in many respects, most unfortunately contains all the varieties of the pathogenic or disease germs, and in scarcely reduced numbers from those which are found in the crude sewage itself. . . . From a chemical point of view there may be no objection to an effluent from contact beds, but from a bacteriological point of view it is a most dangerous effluent to discharge into a river like the Dee. There is not the least doubt that a much higher degree of purification is attained by true aerobic filters than by contact beds, practically all the pathogenic germs being destroyed by the process." The Major refers to several cases of people drinking these effluents from aerobic filters with the greatest impunity! I have tasted the Reigate effluent from the Candy-Caink beds, which is very good indeed! Some of these effluents are superior in appearance and analysis to many waters that are supplied to towns for drinking purposes.

Major Tulloch's estimate for a *contact bed* scheme for Chester was £110,000, and the cost of the *aerobic Candy-Caink system* (tenders actually submitted) was £58,700.

In my humble opinion engineering papers are often over-burdened with figures; it has, therefore, been my endeavour hitherto to keep to main principles and actual practice as much as possible. Mr. Pickering, the borough

engineer of Cheltenham, has, at immense labour, prepared "detailed returns" from all the towns and villages using contact and percolation systems. There is no doubt that much valuable information is hidden therein; but I wish the compiler had set one of his pupils to prepare analyses and abstracts thereof, for as it stands it needs more disintegrating and classifying than many of us have time to do for ourselves. However, in glancing over the returns of the percolation systems, I notice that out of the 12 most important cases, 9 have detritus as well as septic or inoculating tanks; that the former are from 15 minutes to 9 hours capacity, and that the latter lie between the limits of 5 hours and nearly 2 days (42 hours), 3 having about 20 hours and 3 about 12; that the number of gallons per square yard satisfactorily purified in 24 hours on the sprinkler beds ranges from 160 to 850, but that 5 cases were dealing with 400 gallons and upwards, and 3 more between 300 and 400 gallons; that 11 use rotary distributors of the Candy-Caink type, and 2 use fixed ones; that the depths of beds lie between 3 feet 6 inches and 7 feet, there being 8 cases of 6 feet or more. Some further conclusions are: that detritus tanks can be built to intercept most of the mineral matter; that disintegrating tanks of about 20 hours' capacity can be used for 2 years (if not more) without being cleaned out; that aerobic sprinkler beds will run for 5 years, at any rate, without fouling up, as at Reigate; that filtering material smaller than $\frac{1}{8}$-inch or larger than 3 inches does not seem advisable; that there should always be a small chamber or other arrangement to catch the "burnt-out ash," which is found in the purest effluents; that the treatment indicated above gives the best results; and that any comparison must of necessity be arbitrary and approximate until something is done to fix the character

of both crude sewage and effluent Thus we see that the bright "aerobic" star of 1897, is still rising towards its zenith, and, to speak plainly, the Dibdin-Caink aerobic methods, with preliminary treatment, are being found on every hand to be the true ones.

I do not intend to enter into any finely-drawn comparisons of the contact and percolation systems. From what has already been said you will have seen that I am a "percolator" myself. What I should like to see done—and I throw out the thought in the nature of a suggestion—would be for a committee of inquiry into the bacterial treatment of sewage to be appointed somewhat on the lines of the Standardisation Committees, which have done such excellent work. Indeed they might be able to standardise sewage itself, I should think, perhaps by means of a kind of scale, a No. 1 sewage having a chemical analysis between certain limits, so many bacilli per c.c., and so forth. Something should be done, and be done at once, for it is almost impossible to judge of the relative merits of different systems and to get at the truth. We are in a perfectly chaotic condition at present, although a Royal Commission has been sitting for two years; but then there is all that "terrible inertia."

I would submit to your careful attention a rather large and important scheme at present under construction for the treatment of the sewage at Worcester. Two of the drawings are shown. The engineer, Mr. Caink, has most kindly permitted me to make use of his report of September, 1903, and as no one can describe an invention so well as the inventor, I purpose letting him speak for himself. But before doing so I would ask you to notice the novelty of many of the ideas and expedients Mr. Caink has introduced, and to recollect that he was the first civil engi-

neer (so far as I know) to arrive at what are now generally regarded as the correct principles of bacterial purification.

The description of the works is as follows:—

"I propose to convey the sewage first of all into a circular detritus tank, 20 feet diameter and 60 feet deep, having a conical bottom, towards the centre of which the heavy matter will gravitate, and from which it will be removed when required by means of an air lift (which I have designed for the purpose), and carted on to the land. The larger floating matter, such as cloths, scrubbing brushes, dead rats, &c., will be arrested by a wrought-iron screen, which will be provided with a rake at the outlet of the tank, and removed by another application of the air lift.

"If the heavy detritus were allowed to pass into the disintegrating tanks it would be necessary, periodically, to draw off the water in order to remove it. My endeavour is to provide such arrangements that after these tanks are once put into operation they will never require to be emptied, excepting for the purpose of repairs to walls, penstocks, &c., for which I propose to build the tanks in duplicate. I do not intend that it should ever be needed to empty them for the removal of accumulated matter.

"The detritus tank will be roofed with concrete and expanded metal, resting upon steel joists, the roof forming the floor of the room to be used as a store.

"From the detritus tank the sewage will pass to the primary pumps through a cast-iron suction pipe, three feet diameter, common to all the pumps.

"The pumps will be placed in a sunk chamber at such a level that they can be charged for starting by the rise of the sewage itself, without any artificial exhaus-

tion of the suction. This is an advantage in all cases where centrifugal pumps are used.

"I propose that there shall be three pumps, and that they shall have the following approximate capacities—viz., 2, 4, and 6 million gallons per day, respectively. This will enable combinations to be obtained which will economically lift any quantity up to 12 million gallons per day.

"The pumps will deliver the sewage into the disintegrating tanks.

"I proposed to construct these tanks in duplicate with a combined capacity of about 500,000 gallons, or about 6½ hours' flow. I was aware that this was a smaller tank capacity than is generally recognised as necessary for the preliminary to bacterial filters, but the Local Government Board insisted upon our providing a capacity of 1,500,000 gallons, or 18 hours' flow, which has now been done.

"The benefit which was supposed to be derived from the retention of sewage in tanks was that of the solution of its organic suspended matter, and the period of retention was fixed in that connection. Experience, however, has shown that very little real solution takes place in the tank, at any rate within a practicable period, and that the principal effect of the retention is to disintegrate the suspended matter into a state fine enough to pass away on and into the bacteria beds.

"That this failure of the tanks to effect solution is the case was apparent enough to the deputation when they visited the septic tank installation at Exeter. One of the beds was thrown out of use for the purpose of clearing off the surface, which was coated with a deposit of black matter from the septic tanks, which, I believe, have a capacity equal to 24 hours' dry weather flow; other beds had their surfaces so sealed with the deposit that they

lay under 8 or 10 inches of water, that head being required to force the liquid into the body of the filter.

"Now, since it is not the solution but chiefly the mechanical breaking up of the suspended matter that is effected by the tanks, the question for consideration is—Can this be equally well or better done by any other method much less costly? I have for years been persuaded that it may, by means of upward filtration through comparatively fine material. . . .

"With regard to the design of the disintegrating tanks, . . . that I have divided them longitudinally into bays eight feet wide, separated by 9-inch walls, but all communicating with each other at their outlet end, which will prevent any one of them being emptied alone, the thickness of the division walls not being intended to sustain the pressure of the water on one side only.

"The tanks are also divided *transversely* by 9-inch walls, extending to the top, but with arched openings at the bottom.

"The object of dividing the tanks longitudinally into a series of narrow ones is to enable the fine mineral matter or other irreducible deposit which will inevitably accumulate at the bottom of the tanks, to be removed without having recourse to emptying the tanks, by the simple expedient of increasing the velocity of flow by diverting the whole or any portion of the water through any one of them as required. By doing this occasionally, only small quantities will have to be dealt with, and that in the simplest and most convenient manner. The transverse walls will deflect the current through the openings at the bottom, thus increasing the scour along the floor of the tank. The deposit will be conveyed to the secondary pumps, and may either be discharged direct on to the land, or on to the primary filters, to be eventually washed

through on to the land. I propose to roof the tanks with red deal rebated planks, four inches thick, laid on loosely, and covered with a layer of sand four inches thick, flush with the top of the walls, which will be level with the ground. This method of covering affords easy access to the entire surface of the tanks if required, the division walls cutting up the whole into small sections, so as to expose but a small surface at a time. I do not think the covering of the tank adds anything to their efficiency, but from a sanitary point of view, and also from appearance, I think it highly desirable.

"I have already mentioned that the transverse walls extend upward to the top, entirely separating the upper portion of the bays from one another. The effect of this arrangement is to arrest a large portion of the suspended matter which rises to the surface, detain it there (particularly in the bays near the inlet end), in the form of a thick scum more or less dense. If I wished to prevent the accumulation of this scum I should make openings in the cross walls a little below the surface of the water; it would then be gradually carried forward, and get more and more broken up until it finally emerged from the outlet in a condition fit to be transmitted to the primary filters. But I propose to omit the openings in the upper portions of the cross walls for somewhat in the nature of an experiment. I have had this arrangement under observation at the hospital for the past two years, and have been struck with the facility with which the scum, which in course of time becomes almost of the consistency of wet clay, can be removed from the surface by simply digging it out, the specific gravity causing it, when it becomes sufficiently thick, to float well above the surface of the water. Now, as this surface scum is composed chiefly of the solid matters of the sewage, I am disposed

to believe that it will prove to be of sufficient manurial value to be worth taking off and drying, so as to be removable without nuisance.

"I have already experimented in that direction, and when the stuff is dried it can be handled without unpleasantness.

"Disposing of it in this way would also have the advantage of putting less work upon the purification arrangements, which also implies that smaller filters and less land would suffice. If, however, experience shows that it would not pay to remove it, and that it is not desirable to accumulate it in the tanks, then it will only be necessary to provide the openings in the cross walls which I have mentioned.

"The buildings consist of engine-house, producer-shed stores, accumulator-room, office, and workshops, also a manager's house.

"A small dynamo will be provided for lighting the works and for supplying current to motors for driving the fans, for starting or accelerating the producers, and for raising the silt.

"The tank effluent will be raised by the secondary pumps into a circular distributing tower, which will be 20 feet in diameter, and about 15 feet high. The tower will have a flat roof, consisting of steel joists and concrete, strengthened with expanded metal.

"From the tower the effluent will be distributed to the primary bacterial filters, which will be six in number. The filter capacity required by the Local Government Board is based upon the treatment of twice the dry weather flow, with a rate of discharge of 56 gallons per square yard per day per foot of depth of filters. Our dry weather flow is taken at 2,000,000 gallons per day, equal to 40 gallons per head per day for a population of 50,000, which is rather more than that of Worcester.

"56 gallons per sq. yard per foot of depth would require for twice the dry weather flow 107,142 'foot-yards,' if I may be allowed to coin a term, but as it is assumed that half the daily flow is discharged in eight hours—that is, one-third of the 24 hours—50 per cent. greater capacity has to be provided in order to limit the maximum rate of filtration to the standard mentioned. Hence, in one case 160,713 foot-yards will be required, or an area of 20,089 square yards with a depth of 8 feet, as proposed. The area provided in this scheme is 20,944 square yards, having a capacity of 53,500 cubic yards, and is intended to deal with a rate of 6,000,000 gallons per day, or three times the dry weather flow. The filters will be circular in shape, 200 feet diameter, and of an average depth of 8 feet. The filtering material will consist of hard burnt clinkers, slag, saggers, broken bricks, coke breeze, and others of a similar character, occupying the lower portion of the beds, and fine broken stone in the upper part.

"FILTERING MATERIAL.

"It is expected that a large quantity of gravel will be obtained upon the site of the works, which, when screened or broken to about a $\frac{3}{4}$-inch mesh and smaller, will make suitable bacterial filtering material, and be practically indestructible.

"The proportions of this material to the others mentioned will depend upon the facilities and cost at which they can be obtained.

"The beds will be under-drained by means of agricultural butt-jointed pipes and Stiffs' channels, laid radially, falling towards the perimeter into a concrete effluent conduit, running completely round the foot of the slope surrounding each bed. Pipes 5 feet high, surmounted with down draught cowls, are intended to be fixed 10 feet apart

around each filter, communicating with the effluent channel, from which air will be conveyed along the underdrains to the interior of the beds for the purpose of improving the aeration.

"The tank effluent will be distributed on to the primary beds by means of Candy-Caink rotating sprinklers. These sprinklers will differ in design from those hitherto adopted; each will have an arm 95 feet in length, and be supported at the centre and two points along the arm upon rollers moving upon circular paths, carried on concrete arches. The paths themselves will be of glass, a material I have adopted as being non-corrosive and clean. The central pipe of the distributor will form one leg of a siphon, which will convey the water to the arm, which will constitute the other leg of the siphon. The siphon will be of such a height as to afford a maximum head of ten feet upon the arms of the distributor, which enables the size of the arm to be reduced, and the entire distributor consequently lightened. This arrangement also saves the complications of regulating valves for preventing the distributors overflowing, and preserves the greatest simplicity.

"Another advantage possessed by the siphon method of transmitting the water to the arm of the distributor lies in the ability to entirely control the operation of the filters from the engine-house. Any filter can be started or stopped by the man in charge of the engines without going outside the house, by opening and closing two small cocks. When it is borne in mind that the quantity of sewage to be dealt with is constantly varying, the importance of this advantage will readily be understood, as the necessity for increasing or diminishing the number of filters to be put in operation may occur at almost any moment, seeing that no storage capacity, strictly speak-

ing, is provided, but that the water has to be dealt with immediately it is pumped. This advantage is secured by providing a small pipe up the centre leg of each distributor or sprinkler, and extending it to the engine-house; one branch of the pipe is opened to the air, and another is connected to the suction of the pumps.

"To start a sprinkler it is only necessary to open the cock on the latter branch, when the pump will exhaust the air from the siphon and charge it. To stop the action, the other cock is opened, when the air immediately rushes in and destroys the vacuum.

"In addition to this, the siphon method enables all or any of the distributors to automatically discharge the liquid on to the beds intermittingly if desired.

"The rotating distributors will be fitted with my patent sprinkler jets, which have the effect of breaking up the streams of water into a fine spray, thereby exposing an immense water surface to the air for the absorption of oxygen, on which the activity of the micro-organisms, and therefore the purification, largely depends. The breaking up of the water into a fine spray also gives an incomparably better distribution of the liquid over the surface of the beds.

"I did not propose to construct any artificial floors to the filters, as the object is to get as much primary filtered effluent through the loose subsoil as possible. But the Local Government Board have insisted upon concrete floors being provided.

"No question of pollution of wells can arise, as the ground water with which the alluvial deposit overlying the marl is more or less charged is all travelling towards the river.

"Each bacteria bed will be surrounded by a gravel walk with grass verges, the whole arrangement lending

itself admirably to an attractive appearance. Gauges indicating the water level in the disintegrating tanks and the distributing tower will be fixed in the engine-house, so that the man in charge of the machinery will be able to precisely control the pumps and filters as required to meet the varying quantities flowing to the works without leaving the engine-house.

From the primary effluent chamber a pipe is intended to be brought back by the secondary pumps, so that if at any time a specially concentrated sewage is required to be dealt with, or a higher standard of effluent ever demanded, the filtered effluent can be pumped again through the beds. I attach some importance to this arrangement, as I am persuaded that this is another of the directions along which economy in sewage purification will be sought and found.

"The cost of lifting the water the moderate height necessary to pass it repeatedly through the filters is so small compared to the interest and repayment of the capital outlay involved in the construction of filters, that I have no doubt that the method of securing complete nitrification by more lengthened period of contact with the micro-organisms in continuous filters will be economically found in the repeated transmission of the effluent through the beds. It is a method recognised and adopted in the manufacture of vinegar, which is a purely biological-chemical process; and the micro-organisms in bacteria beds seem to show a wonderful power of developing, in accordance with the conditions under which they are required to work, if sufficient food and exygen are provided.

"I propose to make a connection with the final effluent conduit to the suction pipe of the secondary pumps. The object of this is to occasionally send a comparatively large

quantity of practically clear water at a rapid rate through the filters for the purpose of carrying through, by a kind of scouring process, effete irreducible matter from the filters. By this means I anticipate that the filters will be enabled to work almost indefinitely without interference by keeping the passages between the material free.

"The capital outlay is £62,000; estimated annual cost, £1,558."

MR. GEORGE T. MOORE said the paper was very interesting, and would be of great assistance to many of them. The question of dealing with sewage was an important one, and was a subject which all of them had to deal with at some time or other. He had no doubt that the author would admit that the precipitation systems, such as had been designed on such large scale in dealing with sewage of cities, were undoubtedly the best. But they could not always adopt these, owing to the enormous cost and quantity of land that was necessary for these schemes. What they wanted was some effective method of dealing with small quantities of sewage.

He was rather disappointed when he heard the author's criticism of the septic tank system. As far as he could see all the other systems were much the same, one with the other, and he would like to know why the author did not approve of the septic tank system, or would he point out its imperfections. He would also like to know why the author considered that if the septic tank was provided with a spray sprinkler and sand filter it would not be as good a method as some of those he approved of, especially as it was adopted by many eminent engineers. Many engineers preferred the method of distributing sewage over the ground surface, thus allowing it to percolate through before reaching the streams, and he would like

to ask the author if this system was better than the septic tank system or any of those dealt with by him in his lecture, for small sewage schemes, as he held with this system the ground must in time become saturated and thus cease to be a filter.

Mr. R. M. Butler said he thought that Mr. G. T. Moore must have misunderstood the author of the paper, for, as he understood it, the author had not advocated the chemical precipitation system, but, on the contrary, had spoken chiefly of the bacterial process.

He thought it was generally admitted that the precipitation system had had its day. The only question now was whether it was desirable or not to apply chemicals before passing sewage to a tank or other means of bacteriological treatment. The general view was that the addition of chemicals was neither necessary or desirable.

He did not understand the author as recommending the "septic tank" or any particular patent at all, but simply the bacteriological system of purification; although, of course, the author appeared to be in agreement with the general principles of the septic tank system. It was only a matter of detail as to which system gave the best results, and it seemed hard to get reliable information. The Royal Commission had issued many large volumes of evidence, and he had lately read a digest thereof, but he could not say that he had learned very much; in fact, it had disturbed any knowledge he had on the subject of the ideal treatment of sewage so conflicting was the evidence.

He gathered from the paper that the author advocated that there should invariably be some preliminary process of treatment in a tank prior to treatment in contact beds, filters, or land. Those methods of treatment varied very considerably, but he agreed that there should be preliminary treatment.

The author had emphasised that there should be proper filtration before an effluent was finally discharged into a stream, and he agreed with the author as to the great necessity for proper purification.

He would like to ask the author why the tanks in the Ems system were made in such a rather peculiar shape.

Mr. Bergin said the paper contained a lot of information given in a very concise and convenient form. With regard to the final purification of the tank effluent he believed that land treatment was of very little use unless they could get a sufficient quantity of land of the right kind.

Mr. Tomlinson said the paper was extremely interesting, but there was just one point which he thought the author might elucidate. That was in what degree the final contact with air and sunlight was responsible for the result. Because, he thought, that was the kernel of the whole question.

He thought it was quite possible that the microbic action was over-rated, and, especially having regard to the minute division of sprays, that the air and sun had by much the most to do in the purification.

Mr. Purcell said he had listened to the paper with great interest. He would also like to ask the author about the point raised by Mr. Tomlinson—the question of the so-called septic action.

He believed the whole cause of the action rested upon the volume of the atmosphere that passed over the tank and the amount of sunshine.

He would like to ask the author as to the difference in the effluent on dark and wet days as compared with bright and sunlit days, also when there was a good wind blowing, especially when the wind was from the east. They

all remembered the action of the east wind on the plague of locusts—how it killed them—and it might also kill the more modern microbe.

He considered that information on this subject of sewage treatment was of extreme value to every member of the Institution, because in those days of sanitation and so-called sanitation these things were coming more and more to the front, and it was necessary that they should have all the information possible about the best methods.

Mr. Hayes, in reply, said with reference to the septic tanks, what took place in them was a putrefactive process, and that consequently, in his opinion, they should be regarded as merely the preliminary to the true aerobic treatment. At the same time it was absolutely necessary that there should be some such preliminary process, whether in the so-called septic or other tank. If the sewage happened to pass a few hours in a sewer or elsewhere a digestive process took place (what is termed "septic" action), and this was of great assistance in the subsequent treatment of the effluent by aeration.

With reference to land treatment, this might be all very well when they could get a suitable subsoil together with an unlimited acreage cheaply, but usually circumstances were quite the reverse, and the trend of modern conditions of existence pointed towards the more compact and efficient system of filter beds.

In speaking of Mr. Caink's Worcester works he had entirely omitted his description of the secondary purification. Mr. Caink's original idea was to lay down long horizontal gravel beds, formed of the alluvium *in situ*, for the sewage to travel in from the primary beds, always, of course, in the direction of the river, but that had been too much of an innovation for the Local Government

Board, and so large sand filters of the ordinary water-works type were being constructed. The "septic" tank was a "disintegrating" or inoculating tank.

With reference to the shape of the tanks and filters in the Ems system, they had adopted the circular form wherever possible, as being the most economical.

As to the principle of the microbe being rather over-drawn at the present time, he did not know if such was the case. He had never seen a microbe. There were always people who ran from one extreme to another, but he believed in endeavouring to run on an even keel and taking moderate views wherever possible.

With reference to the action of the wind and the difference in the effluent on light and dark days, he had no data, he was sorry to say, from which he could reply to that question, but it was his own opinion that when a strong wind was blowing they would get a better effluent, other things being equal.

In answer to the question as to what beneficient action the air and sun had, he certainly thought, from his own experience, that it had a good deal to do with it, but as he was neither a bacteriologist nor a chemist he could not speak authoritatively.

He had omitted to mention many other points of the Worcester works for the sake of brevity, but would like to draw attention to the air pipes with down-draught cowls placed ten feet apart on the circumference of the primary beds to increase the aeration.

He would advise those who were sufficiently interested to visit the Worcester works now under construction.

COUNCIL.

President:

ROBERT COCHRANE.

Vice-Presidents:

WILLIAM ROSS (*Hon. Treas.*) | BERKELEY D. WISE.

Other Members:

WM. ANDERSON,
PETER CHALMERS COWAN,
JOSHUA H. HARGRAVE,
JOSEPH H. MOORE,
GEORGE M. ROSS,
MARK RUDDLE,
PROSSER A. H. SHAW,
RICHD. O'BRIEN SMYTH.

Past Presidents:

(*Ex-Officio Members of Council*).

BINDON B. STONEY,
WILLIAM H. MILLS,
JOHN A. F. ASPINALL,
JOHN P. GRIFFITH,
SPENCER HARTY,
THOMAS F. PIGOT,
JAMES DILLON,
EDWARD GLOVER,
JOHN H. RYAN.

Honorary Secretary:

MARMADUKE BACKHOUSE.

Bankers:

ROYAL BANK.

REPORT OF COUNCIL FOR THE SESSION 1904–1905.

THE Council in presenting their Report on the work accomplished by the Institution during the Session 1904–5 are pleased to be able to note a continuance of its prosperity. The roll has been added to during the Session by the election of 5 Members and 17 Associate Members.

The number of Members, &c., at the close of the Session (allowing for deaths and resignations), as contrasted with the previous one, are:—

	Members	Associate Members	Associates
1904–5 -	159	84	49
1903–4 -	154	67	50

The revised Bye-laws passed at the General Meeting in May, 1905, will come into operation on January 1st, 1906, and the duties of the Secretary, appointed by the Council, commence on the same date.

Members will note that an office will be opened on the premises of the Institution, and that the Secretary will be in attendance between the hours of 3 p.m. and 5 30 p.m. to answer enquiries. The Council hope that the result of these changes will be to increase the usefulness of the Institution to its Members.

The Rules and Syllabus of the Examination for Associate Members not otherwise qualified for election have been passed by the Council. Copies of these have been forwarded to every Member, and will come into operation

during the coming Session. These regulations, it is hoped will increase the value of the Institution's diplomæ.

During the past year the premises of the Institution have undergone extensive repairs, which have been satisfactorily carried out. The dilapidated condition of the front of the premises required that the necessary expenditure on this account should be incurred.

The Library has been further added to during the past year. The Reading Room is open daily for the use of Members, furnished with the current Engineering periodicals; books can be borrowed on application to the Secretary. The Council hope that Members will take advantage of the facilities there offered to them.

The Council heard with regret of the decease of the late Alexander M'Donnell, Esq., Past-President of the Institution, who was upwards of 44 years a Member of the Institution, and who, by his wise advice and numerous contributions to the "Proceedings," did much to promote its best interests.

The accounts of the Institution have been audited by Messrs. Craig, Gardner & Co., and with their report are presented herewith.

The following are the Papers read before the Institution during the Session 1904–5 :—

November 2nd, 1904.—"The Lorain Surface Contact System of Electric Traction." By Mr. John Rochford, Assoc. Member.

December 7th, 1904.—Inaugural Address. Dr. Cochrane, President.

January 4th, 1905.—"Recent Works of Sea Defence at Penzance." By Mr. Frank Latham, Member.

February 1st, 1905.—"The Closing of the Breaches of the Myroe Embankment, County of Londonderry." By Mr. Berkeley D. Wise, Vice-President.

March 1st, 1905.—"On the Use of Photography for Recording Continuous Soundings during the Progress of River, Canal, Harbour, or Estuary Excavations." By Mr. James Dillon, Past-President.

"On the Most Economical Span for Long Girder Bridges with Numerous Spans of Equal Length." By Dr. Bindon B. Stoney, Member.

April 5th, 1905.—"Further Advances in the Study and Treatment of Sewage." By Mr. W. Kaye Parry, Member.

May 3rd, 1905.—"Some Notes on Bacterial Purification." By Mr. J. G. L. Hayes, Assoc. Member.

The following Medals and Premiums, awarded by the Council, were presented :—

Mullins Gold Medal to W. E. Lilly for his Paper on "The Weight of Plate Girders."

Mullins Silver Medals to—

E. C. H. Walker for his Paper on "Modern Foundry Practice."

A. R. Galbraith, Assoc. Member, for his Paper on "Iron, Steel, and Concrete Construction."

Frank Latham, Member, for his Paper on "Recent Works of Sea Defence at Penzance."

J. G. Hayes, Assoc. Member, for his Paper on "Some Notes on Bacterial Purification."

The marked thanks of the Council were accorded to—

Sir Howard Grubb, Hon. Member, for his Paper on "Some Simple Forms of Geodetical Instruments."

R. G. Allanson-Winn, Member, for his Paper on "Further Notes on Sea Coast Erosion."

John Rochford, Assoc. Member, for his Paper on "The Lorain Surface Contact System of Electric Traction."

Berkeley D. Wise, Vice-President, for his Paper on "The Closing of the Breaches on the Myroe Embankment."

James Dillon, Past-President, for his Paper on "The Use of Photography for Recording Continuous Soundings during Progress of River, Canal, Harbour or Estuary Excavations."

Dr. Bindon B. Stoney, for his Paper on "The Most Economical Span for Long Girder Bridges, with Numerous Spans of Equal Length."

W. Kaye Parry, Member, for his Paper on "Further Advances in the Study and Treatment of Sewage."

AUDITORS' REPORT FOR 1904.

TRINITY CHAMBERS, 40 & 41 DAME-STREET,
DUBLIN, *27th February*, 1905.

THE COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS,
35 DAWSON-STREET, DUBLIN.

DEAR SIRS—We annex for your information copy of the Balance Sheet of your Institution made up to the 31st December last, and copy of the Revenue Account for the year ended same date as extracted by us from your Books.

REVENUE ACCOUNT.

The Income for the past year amounted to £551, and is £30 less than for the preceding year, whilst on the other hand the Expenditure for the past year exceeds that of the previous year by £18. Now the result of this reduction in the Income and increase in Expenditure is to increase the deficiency of Income to meet Expenditure by £50.

The net deficiency of Income for the year 1903 was only £8 16s. 3d., but for the past year it was £58 5s. 8d.

This deficiency of Income to meet outgoings, which has been going on for the years 1901, 1902, 1903, and 1904, will, we have no doubt, have your careful consideration, and if possible the Income will either be increased to meet the outgoings, or the outgoings decreased so that the Income may be sufficient.

We are pleased to see that the Liabilities are now recorded upon the books of the Institution in accordance with our suggestion of the 11th February, 1904.

We are,
Yours faithfully,
CRAIG, GARDNER & CO.

THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND

BALANCE SHEET, 31*st December*, 1904.

LIABILITIES.				£	s.	d.	ASSETS.				£	s.	d.
By Sundry Creditors—							To Subscriptions in arrear 31st Dec., '04			£21 10 6			
Rent Accrued			£22 15 0				Less Subscriptions in advance 31st Dec., '04			5 15 6			
Repairs			12 0 7								15	15	0
Printing and Stationery			241 7 11				„ The Mullen Bequest, £1,172 8s. 3d., 2½ per cent. Consols				1,172	8	3
Expenses General Meeting			26 9 6	302	13	0	„ Smith Testimonial Fund, £97 14s. 7d., 3½ per cent. India Stock				97	14	7
							„ India 3 per cent. Stock, £135 4s. 6d.				149	15	3
							„ Rents receivable due				75	10	0
							„ Dividends on Investments due				26	9	9
							„ Rates in advance				10	3	4
							„ Cash in Bank 31st Dec., 1904				294	18	9
„ Surplus to the credit of the Institution at 31st December, 1904, exclusive of the value of Premises, Library, Furniture, and Fittings as per last account,			1,598 7 7				„ Premises, 35 Dawson-street, Dublin, held under lease for 200 years from 1892, subject to annual rent of £105 and rates				—		
Less—Excess of Expenditure over Income for 1904			58 5 8				„ Library				—		
				1,540	1	11	„ Furniture and fittings				—		
		Total £		1,842	14	11			Total, £		1,842	14	11

THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

Dr. *Revenue Account for Year ending 31st December, 1904.* Cr.

INCOME.	£	s.	d.	EXPENDITURE.	£	s.	d.
By Entrance Fees	38	17	0	To Printing, Stationery, and Postage	220	8	2
„ Subscriptions	338	11	6	„ Rents payable	96	6	8
„ Rents Received	135	0	0	„ Rates, Taxes and Repairs	61	11	2
„ Dividends received	35	7	0	„ Salaries, Fuel and Light	110	17	7
„ Sale of "Transactions" and amount received for binding, &c	2	19	11	„ Annual Dinner	26	9	6
„ Balance being excess of Expenditure over Income for 1904	58	5	8	„ Books and Papers for Library and Reading-room	3	18	0
				„ Furniture	32	4	1
				„ Expenses—General Meeting	14	9	0
				„ Painting, Plastering, &c.	39	0	0
				„ Sundry Expenses	3	16	11
Total, £	609	1	1	Total, £	609	1	1

We have examined the foregoing Revenue Account and Balance Sheet, compared same with the Books and Vouchers of the Institution, and found them to agree.

DUBLIN, 27*th February*, 1905.

CRAIG, GARDNER & Co., *Auditors.*

Publications received in exchange for Institution "Transactions."

Engineering.	The Timber Trades Journal.
The Engineer.	The Indian and Eastern Engineer.
The Builder.	Indian Engineering.
The Contract Journal.	Caissier's Magazine.
The Surveyor.	Engineering Record (New York).
Traction and Transmission.	Railway and Tramway World.
Electrical Review.	

The Volumes of "Transactions" are exchanged with the following Institutions, &c. :—

American Academy of Arts and Sciences.	Boston.
American Society of Civil Engineers.	New York.
American Society of Mechanical Engineers.	New York.
Canadian Society of Civil Engineers.	Montreal.
Engineers' Club of Philadelphia.	Philadelphia.
Franklin Institute.	Philadelphia
Institution of Civil Engineers.	London.
Institution of Mechanical Engineers.	London.
Institution of Engineers and Shipbuilders in Scotland.	Glasgow.
Junior Institution of Engineers.	London.
Liverpool Engineering Society.	Liverpool.
Midland Institute of Mining, Civil, and Mechanical Engineers.	Barnsley
North of England Institute of Mining and Mechanical Engineers.	Newcastle
Nova Scotian Institute of Science.	Halifax, N. S.
Royal Engineer Institute.	Chatham.
Royal Institute of British Architects.	London.
Royal Scottish Society of Arts.	Edinburgh.
Royal Society of Antiquaries of Ireland.	Dublin.
Smithsonian Institution.	Washington.
Sociedad Cientifica Argentina.	Buenos Ayres.
Society of Arts.	London
Society of Engineers.	London.
Surveyors' Institution.	London.
West of Scotland Iron and Steel Institute.	Glasgow.

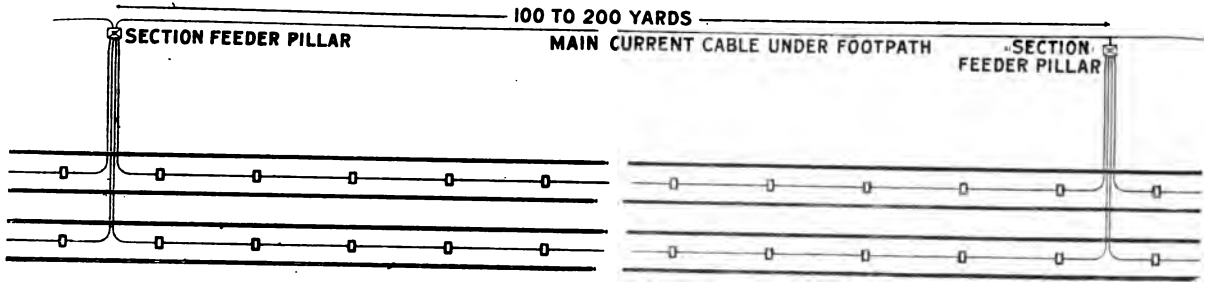


Fig. 1.—Diagram of Connections between Contact Boxes and Main Current Cable.

Fig. 2.

Fig. 3.

Fig. 4.—Queen's Square, Wolverhampton.

Fig. 5.—Newbridge, Tattenhall.

Fig. 6.—Tattenhall Road, Wolverhampton.

THE LORAIN SYSTEM OF ELECTRIC TRACTION.

Fig. 7.

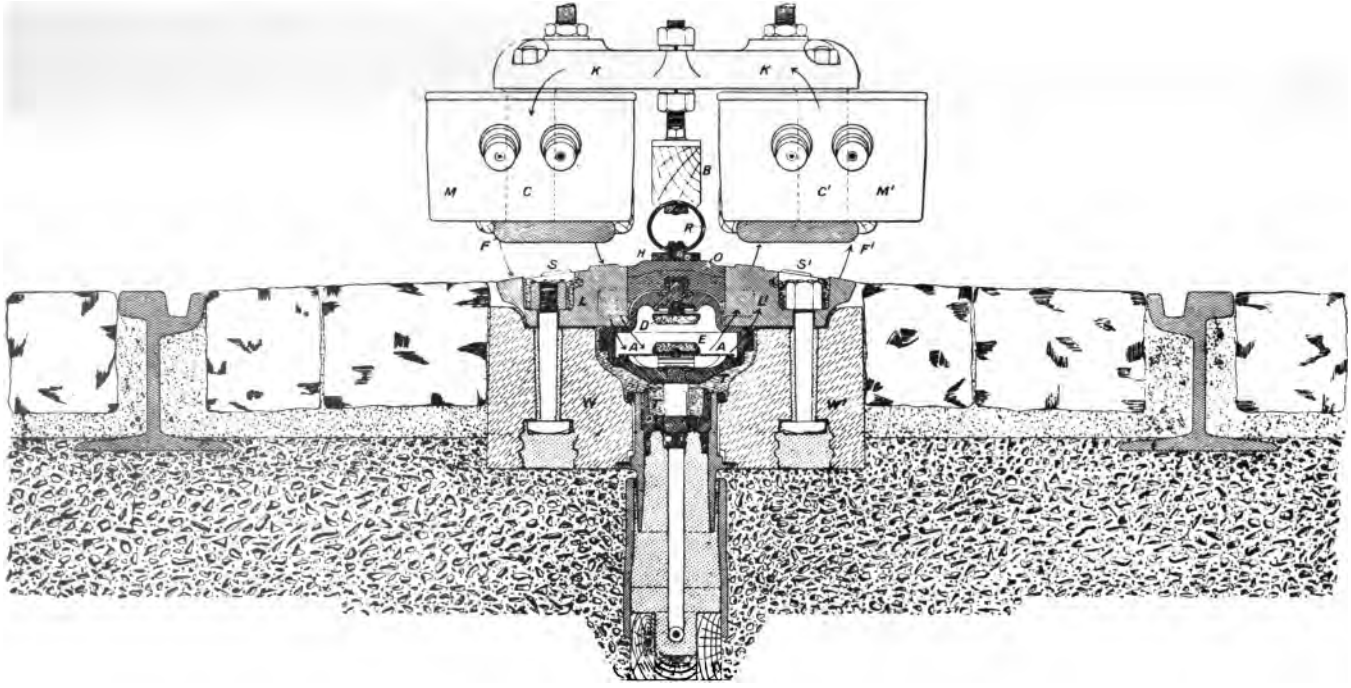


Fig. 8.—Cross Section of Track, showing Section of Contact Box, Magnet, and Contact Shoe.

THE LORAIN SYSTEM OF ELECTRIC TRACTION.

Fig. 7.

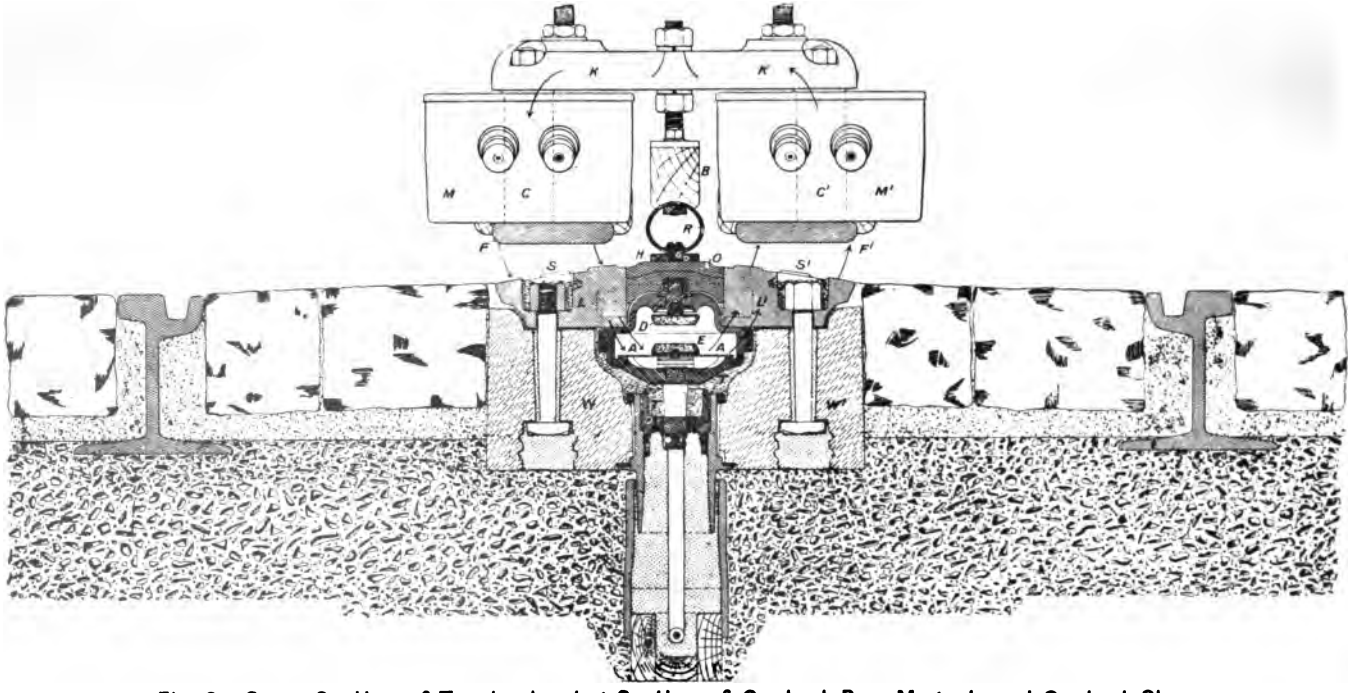


Fig. 8.—Cross Section of Track, showing Section of Contact Box, Magnet, and Contact Shoe.

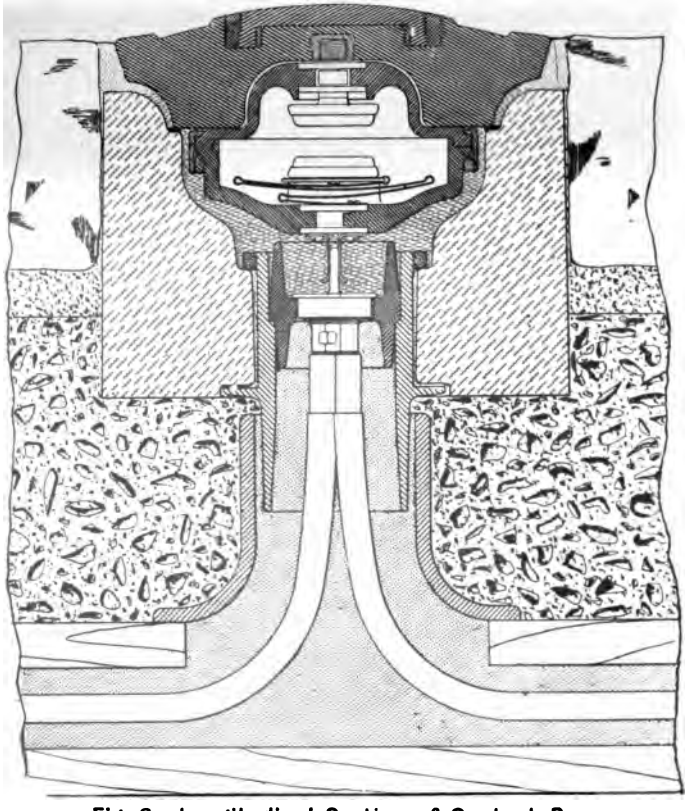


Fig. 9.—Longitudinal Section of Contact Box.

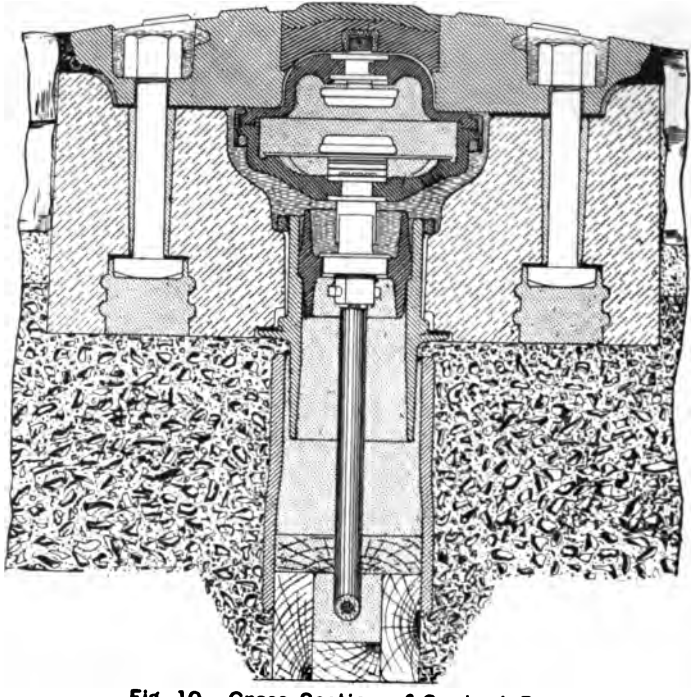


Fig. 10. - Cross Section of Contact Box.

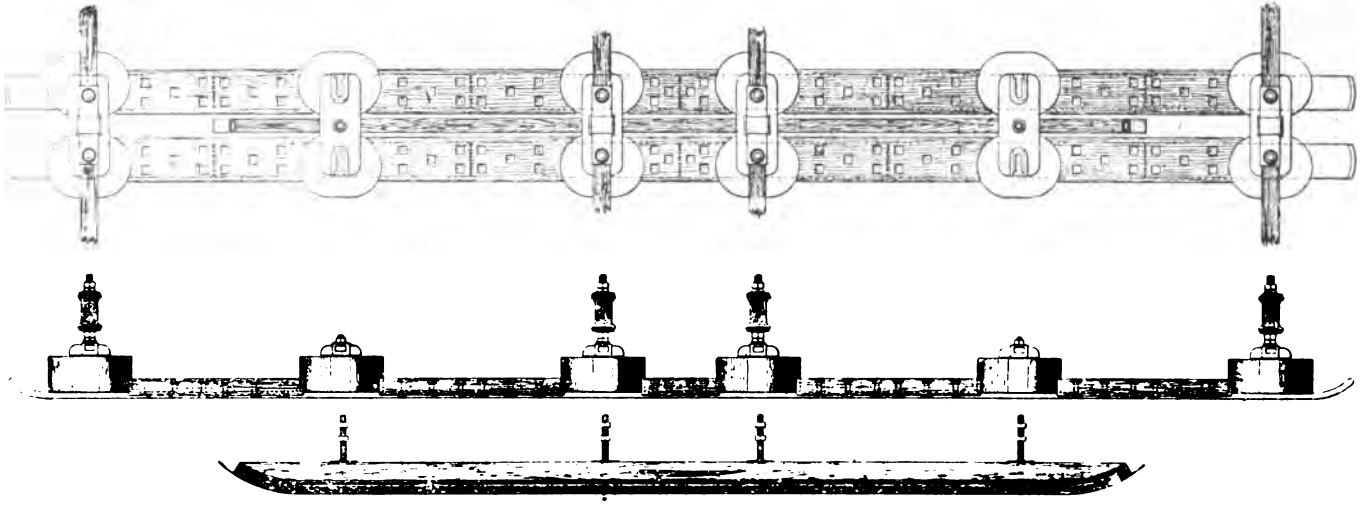
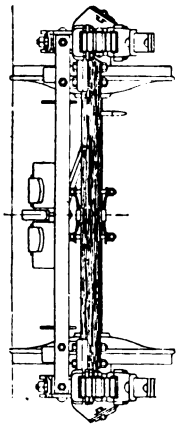


Fig. 11.- Plan and Sectional Elevation of Magnets and Shoe.



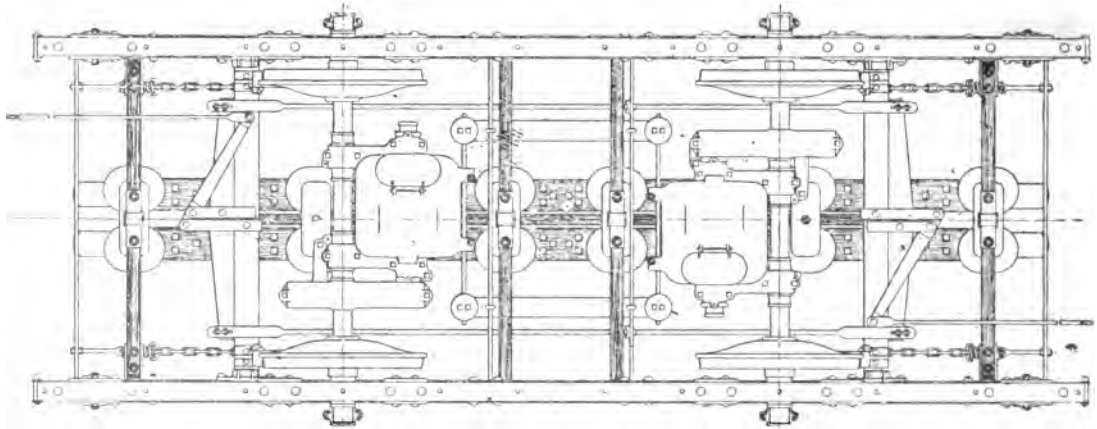


Fig. 12.—Plan of Motor Truck with Magnet and Current Collector.

THE LORAIN SYSTEM OF ELECTRIC TRACTION.

Fig. 13.

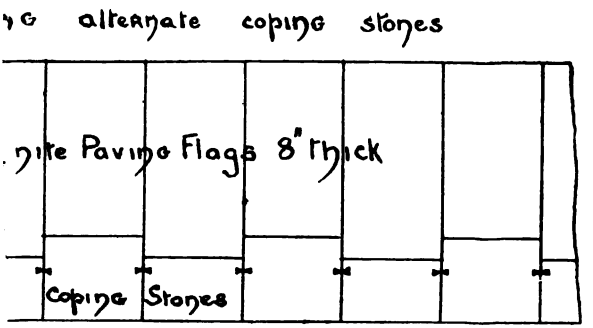
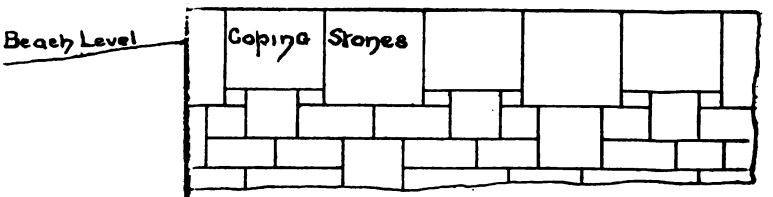
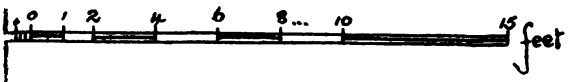


Fig 4



showing alternate coping stones

Fig 5



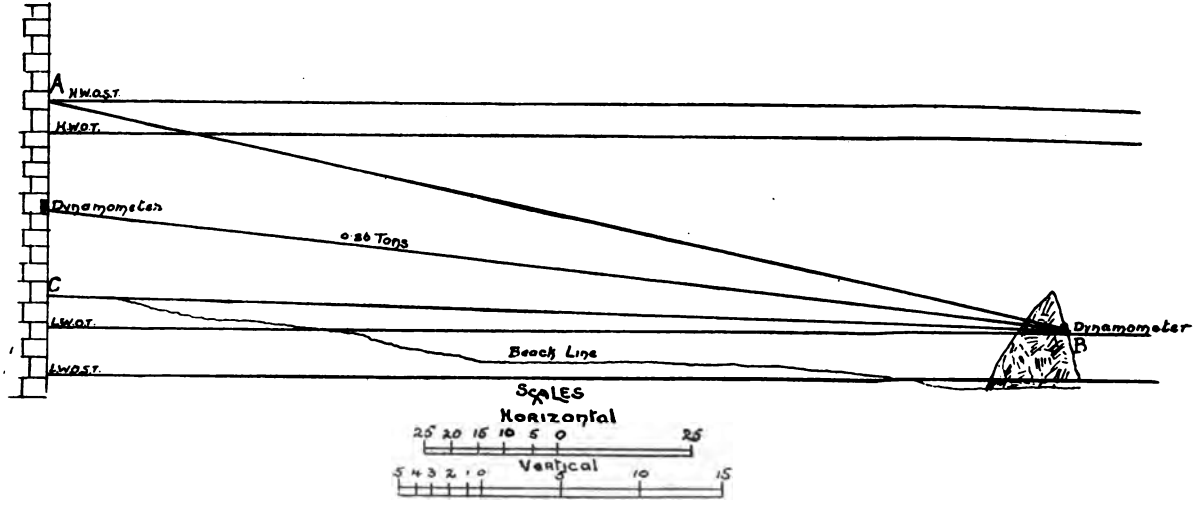

A
H.W.O.S.T.
H.W.O.T.
Dynamometer
0.86 Tons
C
L.W.O.T.
L.W.O.S.T.
Beach Line
Dynamometer
B
SCALES
Horizontal
25 20 15 10 5 0 25
Vertical
5 4 3 2 1 0 5 10 15

Fig 8

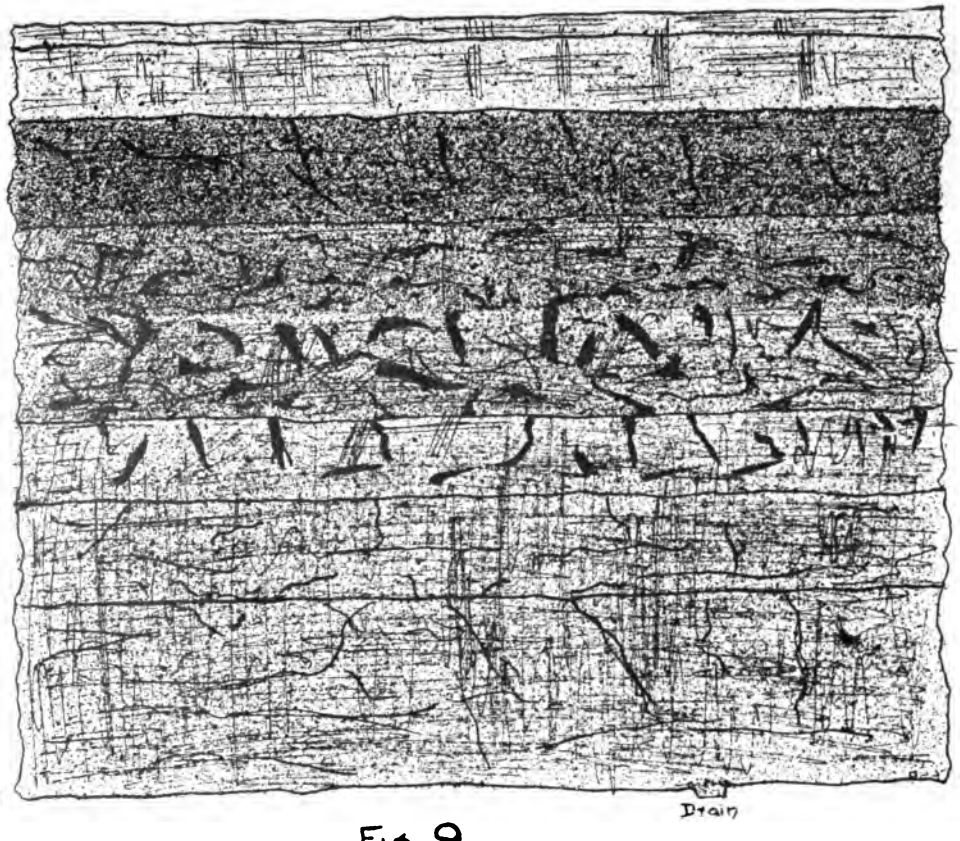

Soil
Pumice Layer
Volcanic Ashes
The Ancients
Water Line
Yellow Tufa
Gray Tufa
Blue Tufa
Floor with drain for Pump
Drain

Fig 9

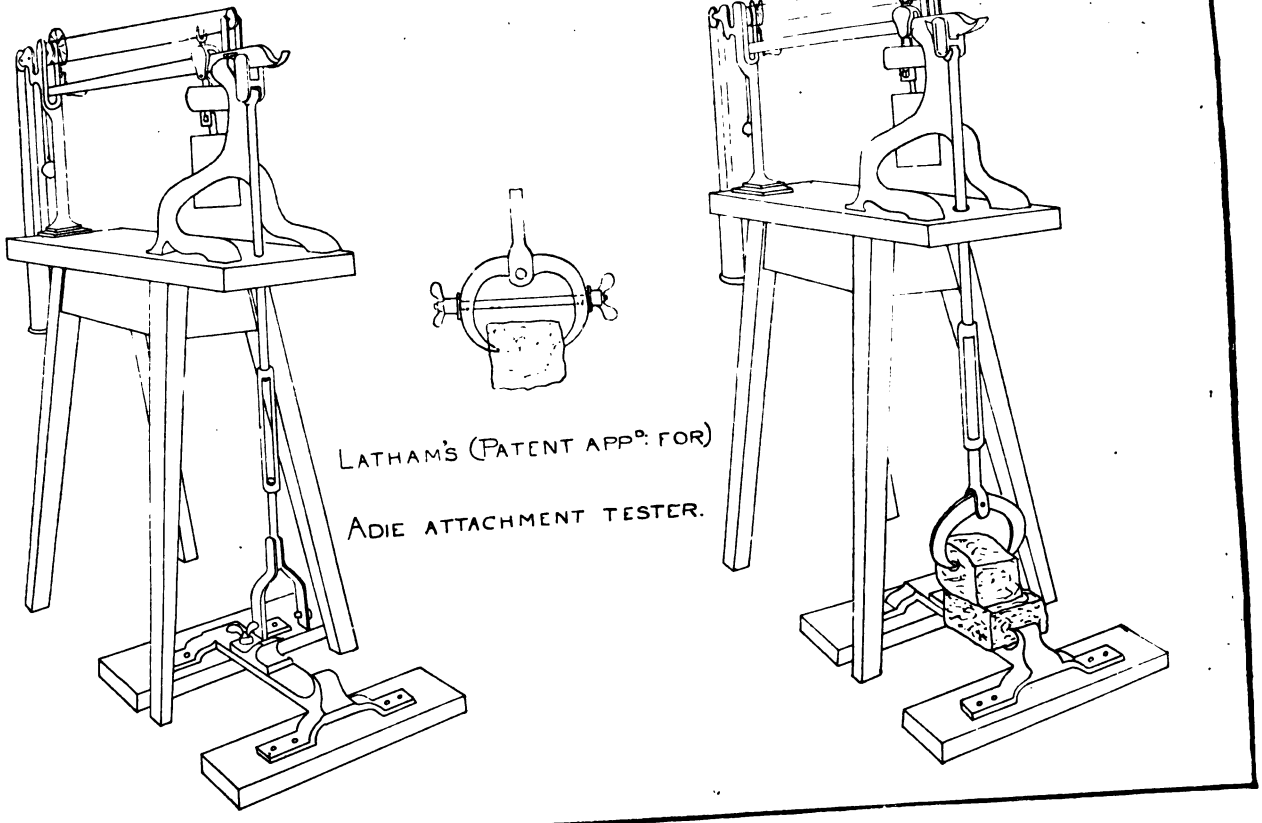
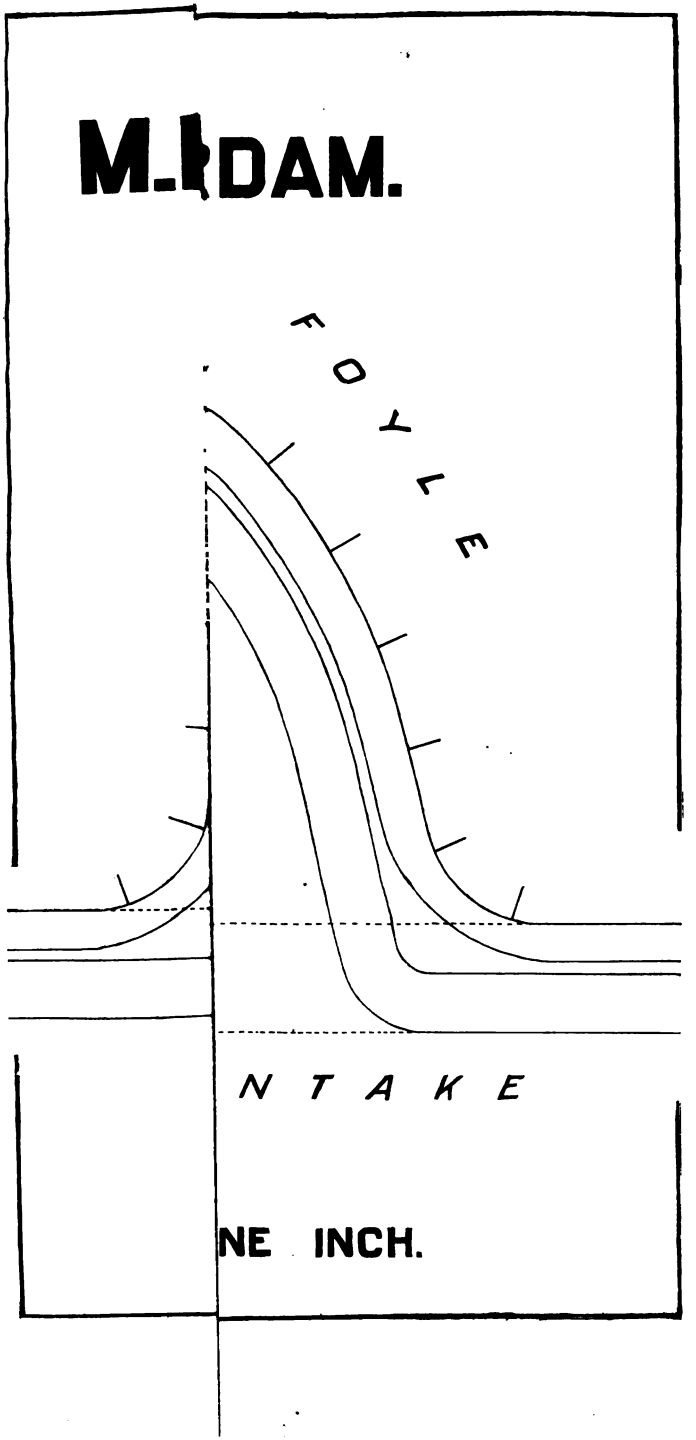
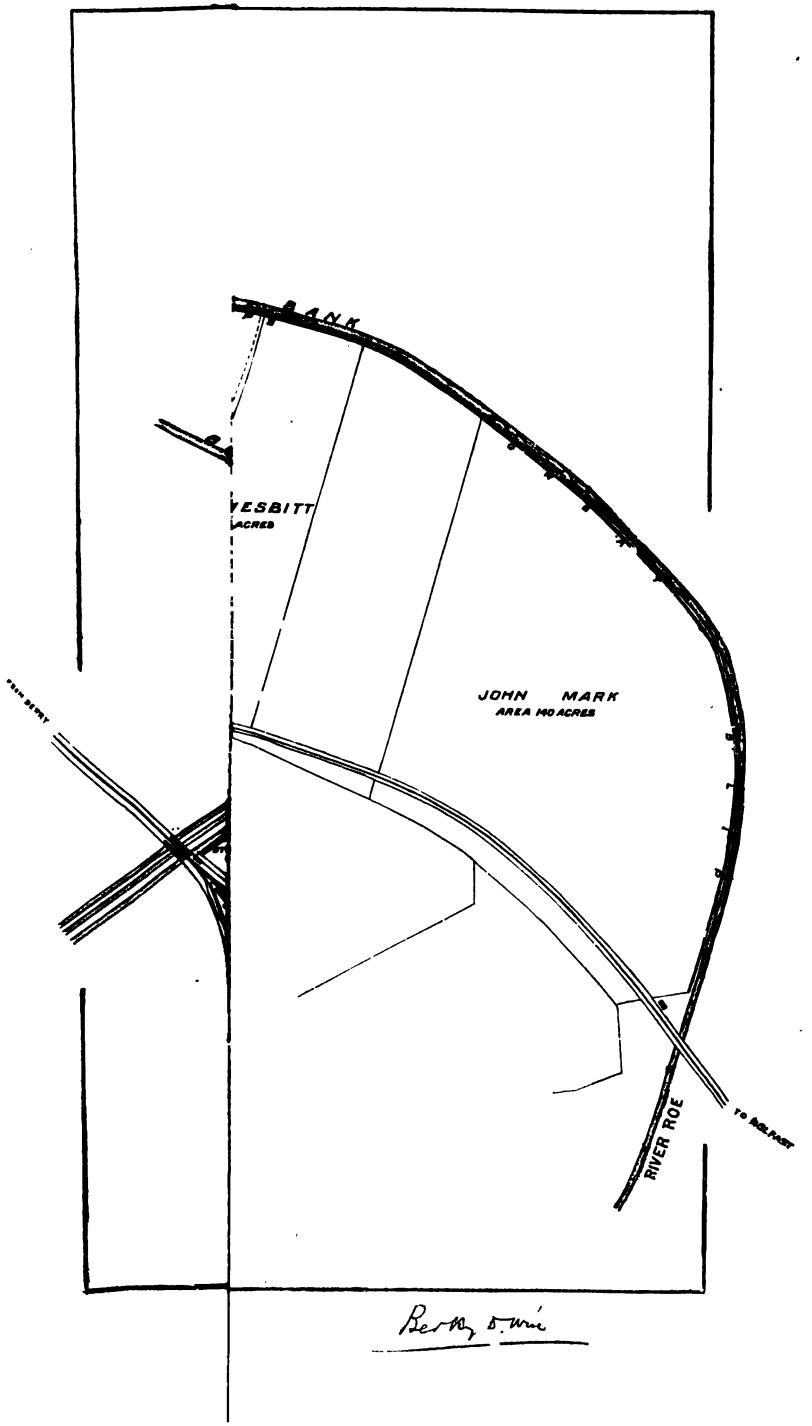
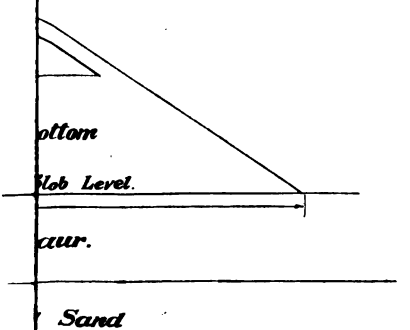


Fig. 10.


M.ŁDAM.
FOYLE
NTAKE
NE INCH.


BANK
VESBITT
ACRES
JOHN MARK
AREA 140 ACRES
RIVER ROE
TO MAGHERA

MENT.



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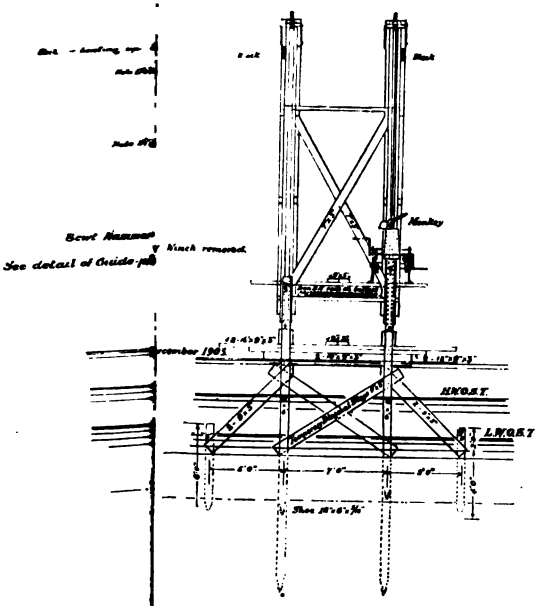
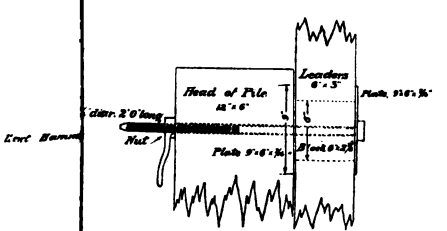
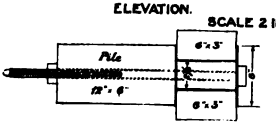


END ELEVATION



ELEVATION.

SCALE 2 INCHES TO ONE FOOT.



PLAN.

TAIL OF PILE HEAD, SHEWING GUIDE PIN, BLOCK, ETC

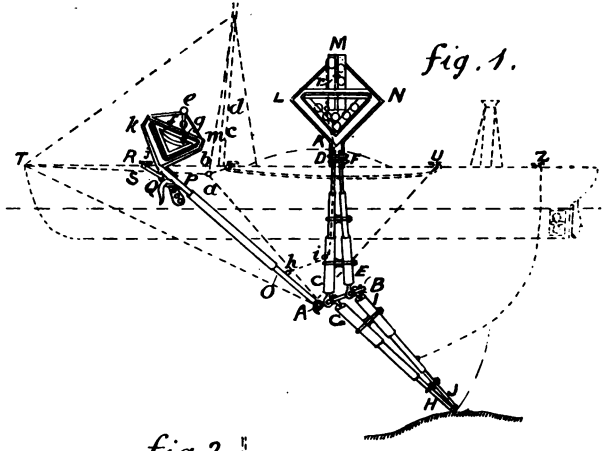


fig. 1.

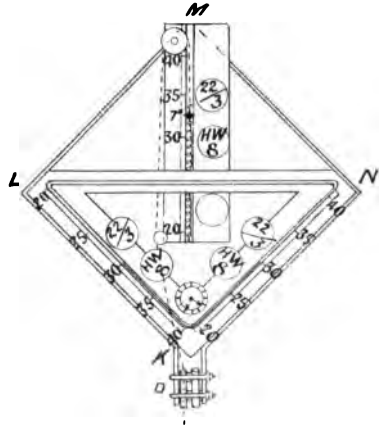
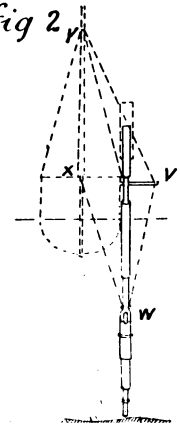


fig 2.



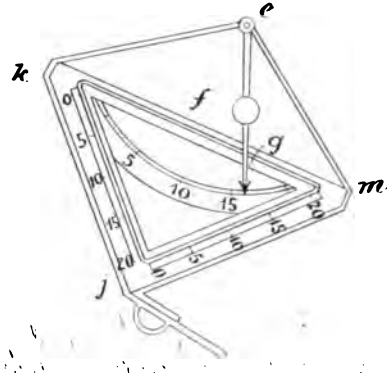


fig. 1A

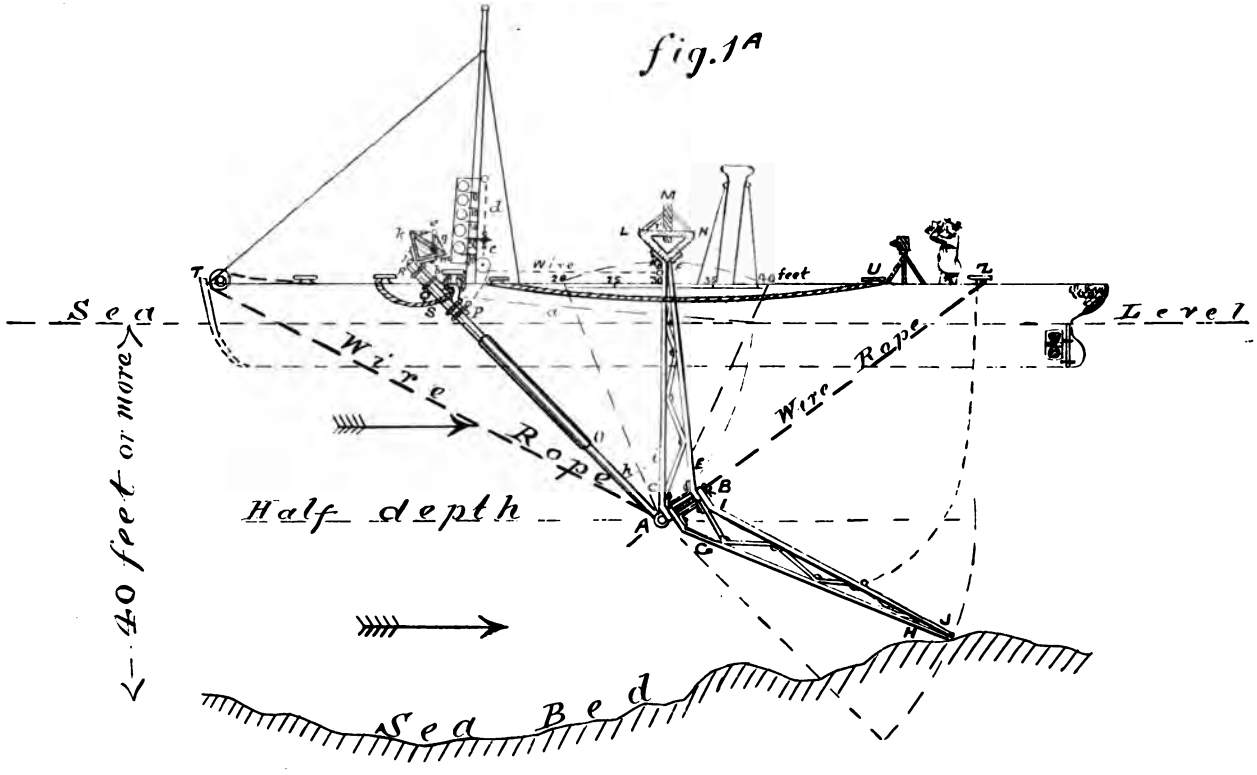
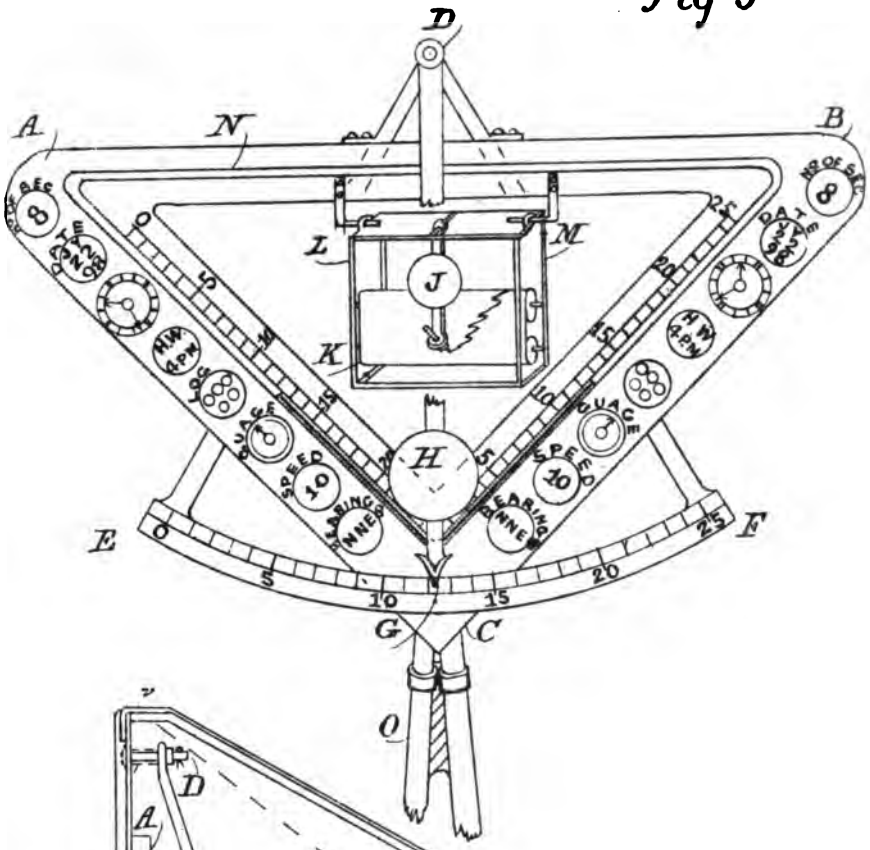

Sea Level
Wire Rope
Wire Rope
Half depth
40 feet or more
Sea Bed
Wire
feet

fig 3



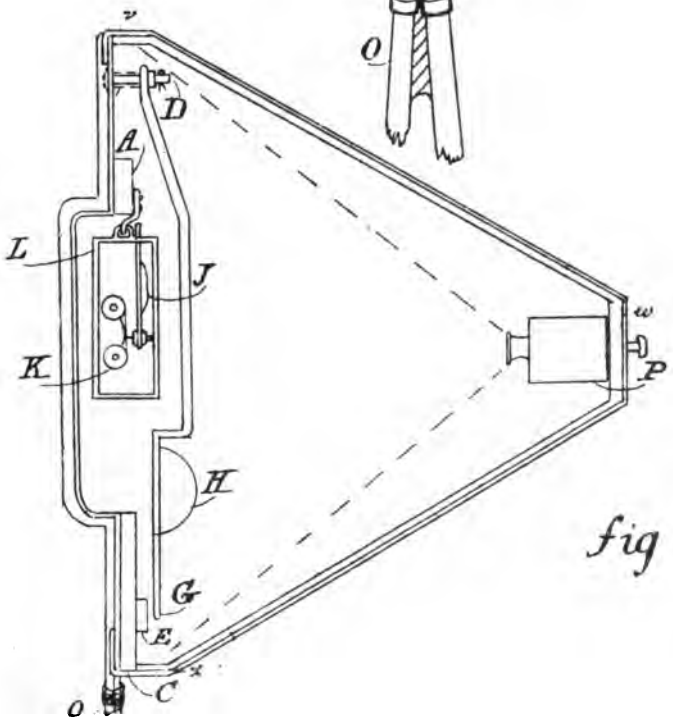
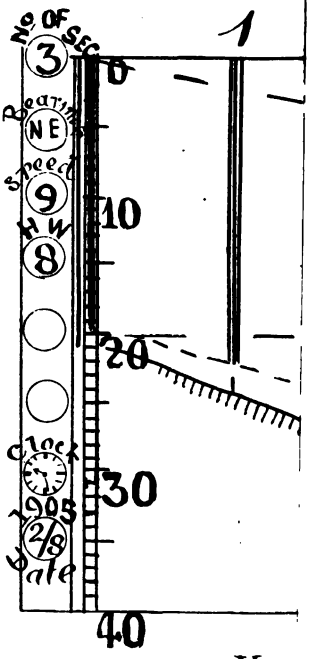


fig 4

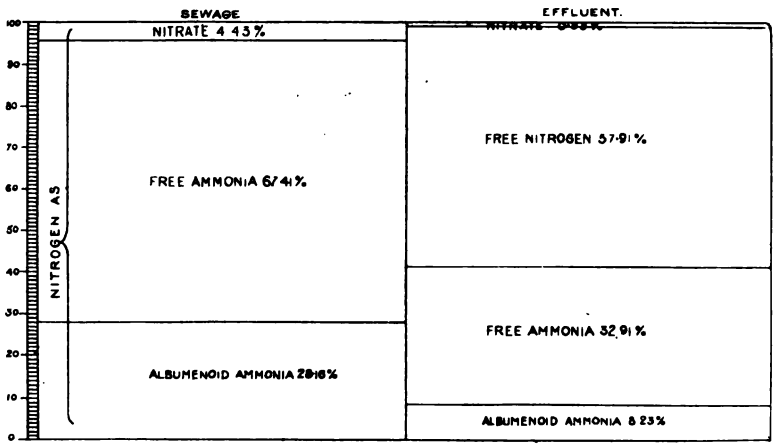


Ver

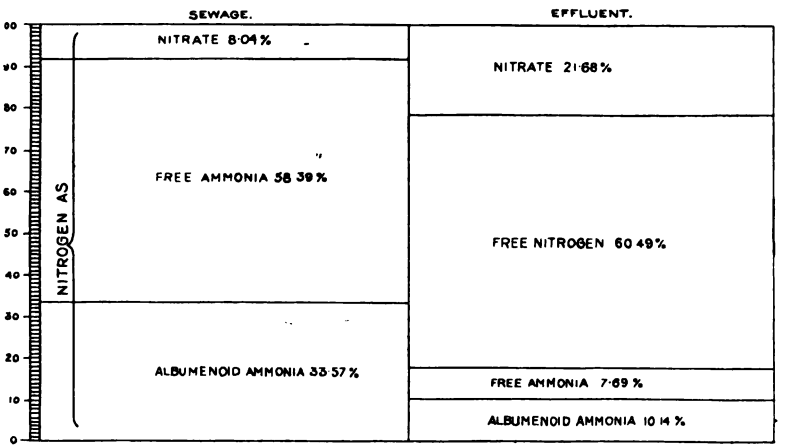
FURTHER ADVANCES IN THE STUDY AND TREATMENT OF SEWAGE.

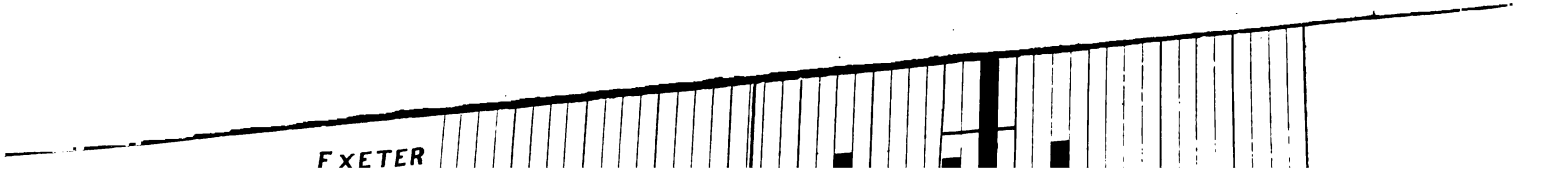
SEWAGE PURIFICATION EXPERIMENTS
BY
Dr. E.A. LETTS.

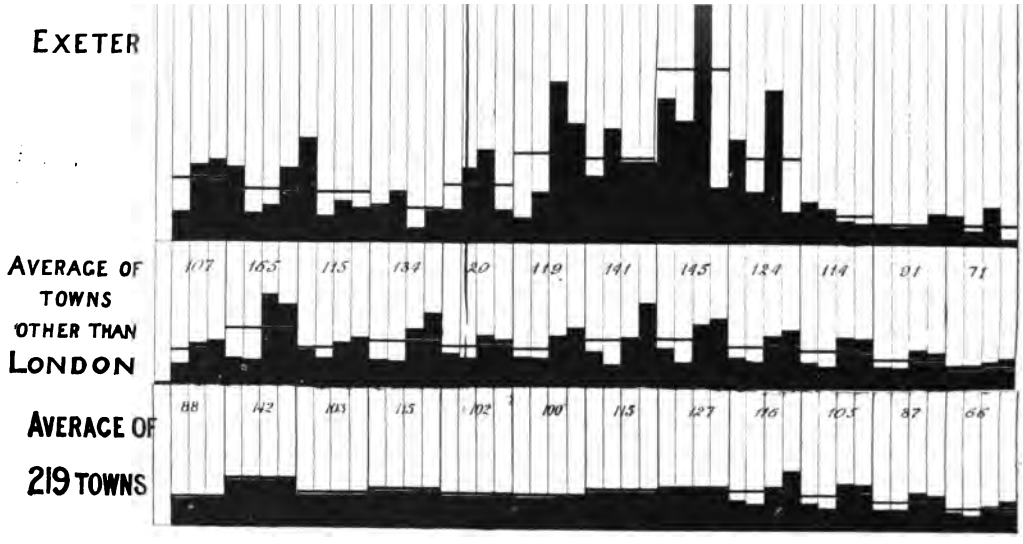
EFFECTS OF TREATMENT IN CONTACT BEDS ONLY.



EFFECTS OF TREATMENT IN CONTACT BEDS PRECEDED BY SEPTIC TANK.




EXETER



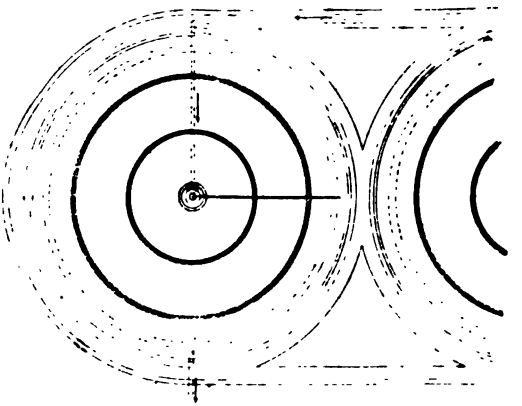
VERTICAL SCALE 1 INCH - 250 CASES PER 100,000 PER ANNUM

The figures in Italics denote the average Typhoid Case-rate per 100,000.

T. CAINE, A.M.INST.C.E.
CITY ENGINEER, WORCESTER

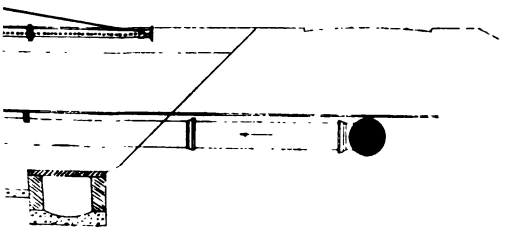
FIG. 2

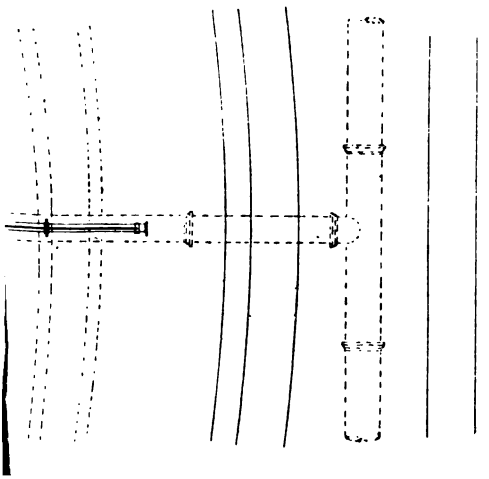
FIG. 2



— BLOCK PLAN —

— SCALE —
40 Feet to 1 Inch





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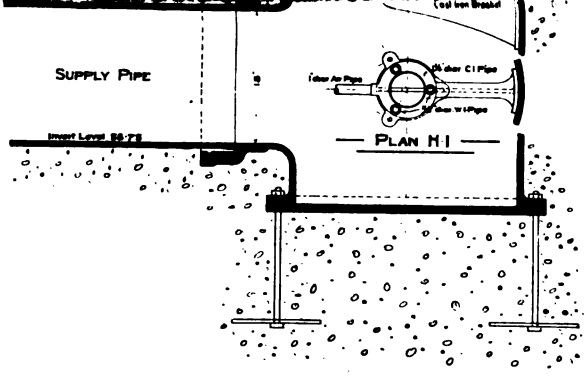
J.C.L. HAVES ON BACTERIAL PURIFICATION

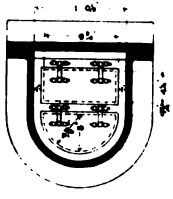
CITY OF WORCESTER SEWAGE DISPOSAL

OUTFALL WORKS

SECTION B-C.



SECTION F.G.



SECTION D.E.

ELEVATION OF FLAP-VALVE

T. CAINK. A.M.I.C.E.
CITY ENGINEER